US Army Corps
of Engineers
Waterways Experiment
Station

Technical Report CHL-97-27
October 1997

Navigation Conditions at Lock and Dam 22, Mississippi River

Hydraulic Model Investigation

by Ronald T. Wooley

Prepared for U.S. Army Engineer District, Rock Island

Technical Report CHL-97-27
October 1997

Navigation Conditions at Lock and Dam 22, Mississippi River

Hydraulic Model Investigation

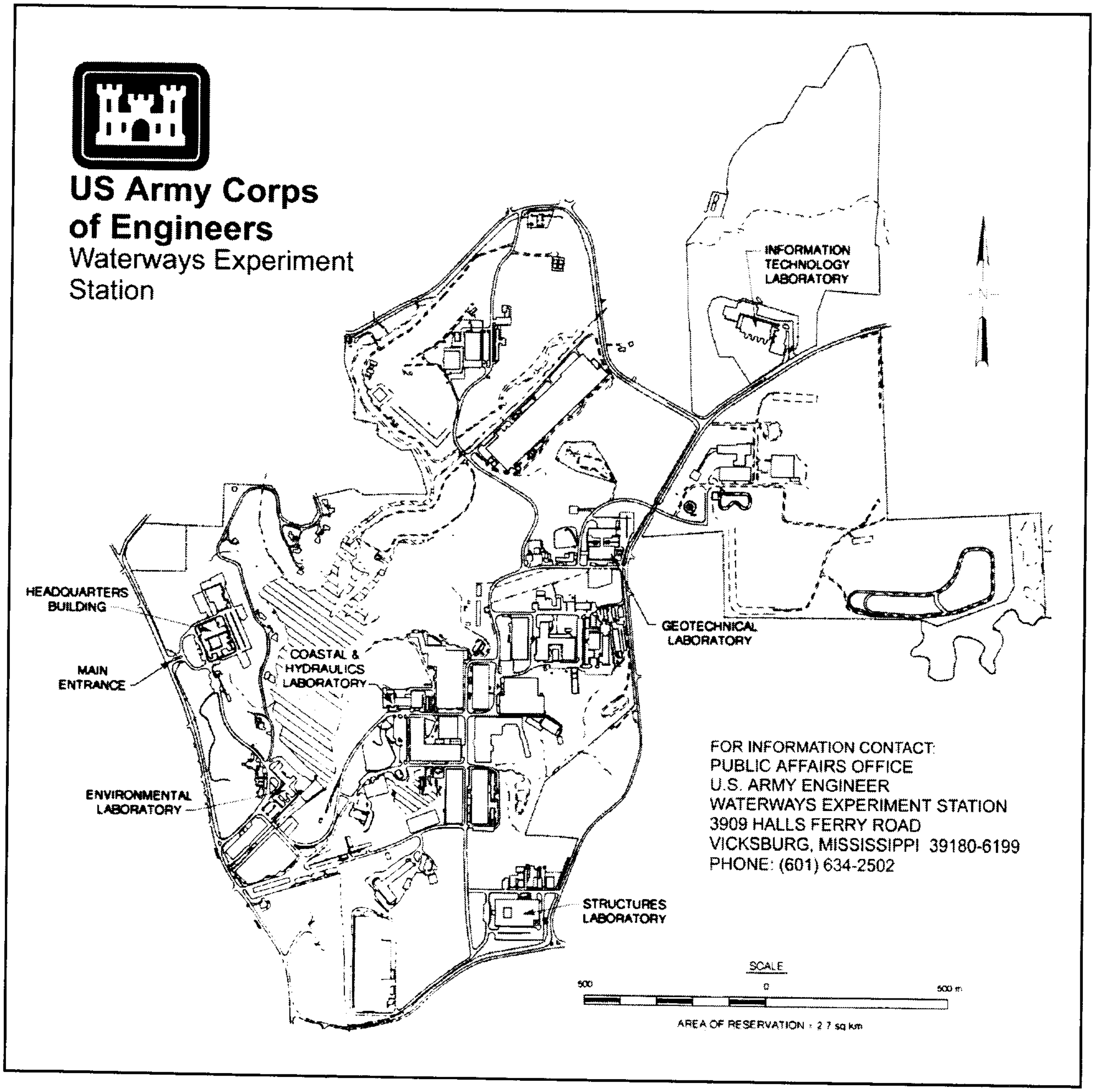
by Ronald T. Wooley

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Engineer District, Rock Island
Rock Island, IL 61204-2004



Waterways Experiment Station Cataloging-in-Publication Data

Wooley, Ronald T.

Navigation conditions at Lock and Dam no. 22, Mississippi River : hydraulic model investigation / by Ronald T. Wooley ; prepared for U.S. Army Engineer District, Rock Island.

87 p. : ill. ; 28 cm. — (Technical report ; CHL-97-27)

Includes bibliographic references.

1. Inland navigation — Mississippi River. 2. Locks (Hydraulic engineering) — Mississippi River. 3. Hydraulic models. I. United States. Army. Corps of Engineers. Rock Island. II. U.S. Army Engineer Waterways Experiment Station. III. Coastal and Hydraulics Laboratory (U.S. Army Engineer Waterways Experiment Station) IV. Title. V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; CHL-97-27.

TA7 W34 no.CHL-97-27

Contents

List of Figures

Preface

The model investigation reported herein was authorized by Headquarters, U.S. Army Corps of Engineers, in an indorsement dated 17 February 1994 to the Division Engineer, U.S. Army Engineer Division, North Central. The study was conducted for the U.S. Army Engineer District, Rock Island (NCR), in the Hydraulics Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES) during the period February 1994 to November 1995.

During the course of the model study, representatives of U.S. Army Engineer Districts, Rock Island, St. Louis, and St. Paul, and other navigation interests visited WES at different times to observe special model experiments and to discuss the experiment results. Rock Island and St. Louis Districts were kept informed of the progress of the study through monthly progress reports and special briefings at the end of each experiment.

The investigation was conducted under the general supervision of Messrs. F. A. Herrmann, Jr., Director of the Hydraulics Laboratory, and R. A. Sager, Assistant Director of the Hydraulic Laboratory; and under the direct supervision of Dr. L. L. Daggett, Acting Chief, Waterways Division, Hydraulics Laboratory. The principal investigator in immediate charge of the model study was Mr. R. T. Wooley, assisted by Messrs. R. A. McCollum, H. E. Park, and B. T. Crawford, and Ms. K. Anderson-Smith, all of the Navigation Division, Hydraulics Laboratory, and Mr. W. L. Hanks of Soils Mechanics Branch, Geotechnical Laboratory, WES. This report was prepared by Mr. Wooley.

This report is being published by the WES Coastal and Hydraulics Laboratory (CHL). The CHL was formed in October 1996 with the merger of the WES Coastal Engineering Research Center and Hydraulics Laboratory. Dr. James R. Houston is the Director of CHL, and Messrs. Richard A. Sager and Charles C. Calhoun, Jr., are Assistant Directors.

During preparation and publication of this report, Dr. Robert W. Whalin was Director of WES. COL Robin R. Cababa, EN, was Commander.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles (U.S. statute)	1.609344	kilometers

1 Introduction

Location and Description of Prototype

Lock and Dam 22 is located on the Mississippi River, 301.2 miles[1] upstream of its confluence with the Ohio River (Figure 1). The principal existing structures are the main 110- by 600-ft lock located along the right descending bank, an incomplete auxiliary lock located riverward of the main lock, and a 1,024-ft dam with ten 60-ft tainter gates and three 100-ft roller gates. An overflow dike with top elevation of 459.5[2] extends from the dam to high ground on the left bank. The dam provides a navigation pool that extends upstream about 24 miles to Lock and Dam 21. The dam is operated to maintain a navigation pool of el 459.5 at the dam. As the riverflow increases, the gates are raised so normal pool elevation of 459.5 will not be exceeded.

History of Navigation Improvements on the Mississippi River

In its original condition prior to any improvements, the navigable channel of the Mississippi River at low water had a natural depth in many places of only 3 ft or less. The main channel was divided by islands and bars that formed chutes, sloughs, and secondary channels through which considerable parts of the low-water flow were diverted to the detriment of navigation.

As early as 1824, the Federal government made appropriations to improve navigation on the Mississippi River from the Missouri River to New Orleans. The project adopted was for the removal of such obstructions as snags, logs, and wrecks. In 1878, Congress authorized the 4.5-ft channel, the first comprehensive project on the upper part of the river from St. Paul, MN, to the mouth of the Ohio River, and in 1907 authorized the 6-ft channel. The increase in depth was obtained mainly by the construction of hundreds of rock and brush dikes, low

---

[1] A table of factors for converting non-SI units of measurements to SI units is found on page vi.
[2] All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD), except where noted.

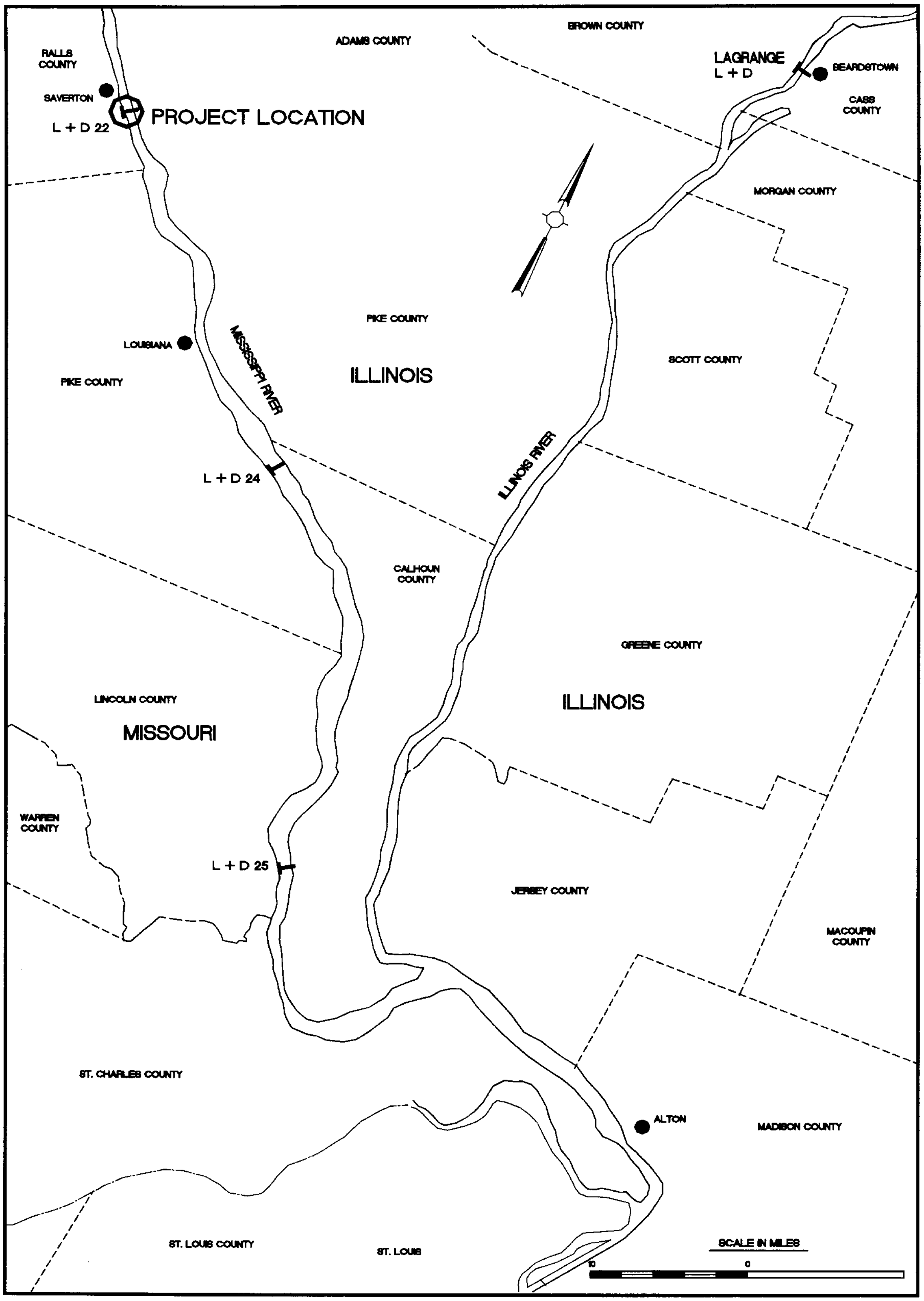


Figure 1. Vicinity map

structures extending radially from the banks into the channel to constrict low-water flows.

A project adopted in 1880 provided for navigational improvements, which included construction of 41 reservoirs at the headwaters of the Mississippi River. The reservoirs in Minnesota and Wisconsin, six of which were constructed, were intended to collect surplus water in the spring and release it during low-water periods. Congress passed an act in August 1894 providing for a separate water project on the Mississippi River between Minneapolis and St. Paul, MN. This project established the groundwork for Locks and Dams Nos. 1 and 2. The channel depth was changed from 5 to 6 ft in 1907, and then on 3 July 1930 the Seventy-First Congress authorized the 9-ft channel. The 9-ft channel from the mouth of the Illinois River to Minneapolis was to be achieved by construction of a system of locks and dams, supplemented by dredging. In August 1935, the lower limit of the project was extended to the Missouri River, and on 26 August 1937, the upper limit of the project was extended to above St. Anthony Falls with extensions into the Minnesota and St. Croix Rivers.

The Mississippi River above St. Louis, MO, includes a system of 28 dams and 29 navigation locks that makes navigation for long-haul commercial carriers possible almost year-round, with the exception of ice stoppage on the upper reaches. The major products moved on the waterway in this area are petroleum and petroleum products, which constitute about 29 percent of all tonnage passing through the locks; about 34 percent in grain, mostly downbound; 16 percent coal; and 21 percent other commodities, such as sulphur, sand, steel, bulk chemicals, and other manufactured items.

Existing Conditions

Dam 22 creates a shallow pool in the vicinity of the dam with numerous islands and backwater areas ranging in depth from less than a foot to several feet deep. The navigation channel meanders through the pool making numerous crossings. The navigation channel favors the left descending bank about 4 miles upstream of the dam, makes a crossing toward the right bank about 3 miles upstream of the dam, and approaches the lock along the right bank. Starting about 9,000 ft upstream of the dam, the right bank curves inland of a straight alignment with the lock. From about 3,000 ft upstream of the dam, the right bank curves to the right to approach the lock and continues turning to the right downstream of the lock. Therefore, the lock is located on the convex side of the bend and demonstrates many of the problems associated with locks located on the inside of bends. Currents tend to follow the bank line in this area to a point about 3,000 ft upstream of the dam and at that point move across the upper lock approach toward the gated dam, creating serious crosscurrents in the approach. Due to the alignment of the channel and crosscurrents, navigation conditions for downbound tows approaching the lock are extremely difficult. Wing dams were constructed along the right bank upstream of the lock; however, available data indicate that currents continue to follow the right bank and adversely affect tows approaching the lock.

A time-lapse video recorder was installed in the field to record navigation conditions for tows entering and leaving the lock approaches during the period December 1993 to October 1994. These data provided valuable information on navigation conditions for a wide range of riverflows. The time-lapse video indicates adverse flow conditions in the upper approach to the lock. A helper boat is used most of the time to overcome the outdraft and align the tow with the guide wall (Photos 1 and 2). The video also indicates that currents moving across the lower lock approach create some problems for tows entering and leaving the lower lock approach. Downbound tows leaving the lock turn riverward as soon as they clear the lock to prevent the currents from moving the tow into the shallow areas along the right bank.

Need for and Purpose of Model Study

Several locations are being considered for a new lock at Dam 22. While sound engineering judgment was used as a screening tool in evaluation of the various proposals, arriving at an analytical solution is very difficult due to the complex nature of the flow through the reach. Therefore, it was considered necessary to determine the conditions that would develop at the various locations with the new lock in place and to identify any structures or channel alignments needed to improve navigation conditions. The purposes of the model study were as follows:

a. Evaluate navigation conditions for each lock location.

b. Identify guard wall lengths, remedial structures, and channel alignment required to establish satisfactory navigation conditions.

c. Identify problems that may be associated with a particular lock location so information can be used in the preliminary design for new locks at other dam sites along the upper Mississippi River.

d. Determine approach times for various lock configurations at low, moderate, and high flows.

2 The Model

Description

The model (Figure 2) reproduced about 3.5 miles of the Mississippi River and the adjacent overbank areas from about 10,700 ft upstream to about 7,700 ft downstream of the existing dam. The model was of the fixed-bed type with overbank areas and channels molded of sand-cement mortar to sheet metal templates set to the proper grade. Portions of the model where changes in bank alignment and placement of new structures could be anticipated were molded in sand and overlaid with a thin layer of sand-cement mortar to facilitate modifications necessary to determine navigation conditions associated with the various plans. The lock, guide walls, guard walls, and dam were constructed of sheet metal and/or Plexiglas and set at the proper grade. The dam gates were simulated schematically with simple vertical sheet metal slide-type gates. The channel portion of the model was molded to conform to a hydrographic survey dated October 1993, and the overbanks were molded to a topographic survey dated March 1994.

Scale Relations

The model was built to an undistorted linear scale of 1:120, model to prototype. This scale allows accurate reproduction of velocities, eddies, and cross-currents that would affect navigation. Other scale ratios resulting from the linear scale ratio are shown in the following tabulation:

Characteristic	Dimension[1]	Scale Relation Model:Prototype
Length	L_r	1:120
Area	$A_r = L_r^2$	1:14,400
Velocity	$V_r = L_r^{1/2}$	1:10.95
Time	$T_r = L_r^{1/2}$	1:10.95
Discharge	$D_r = L_r^{5/2}$	1:157,744
Roughness (Manning's n)	$N_r = L_r^{1/6}$	1:2.22

[1] All relations are given in terms of length L.

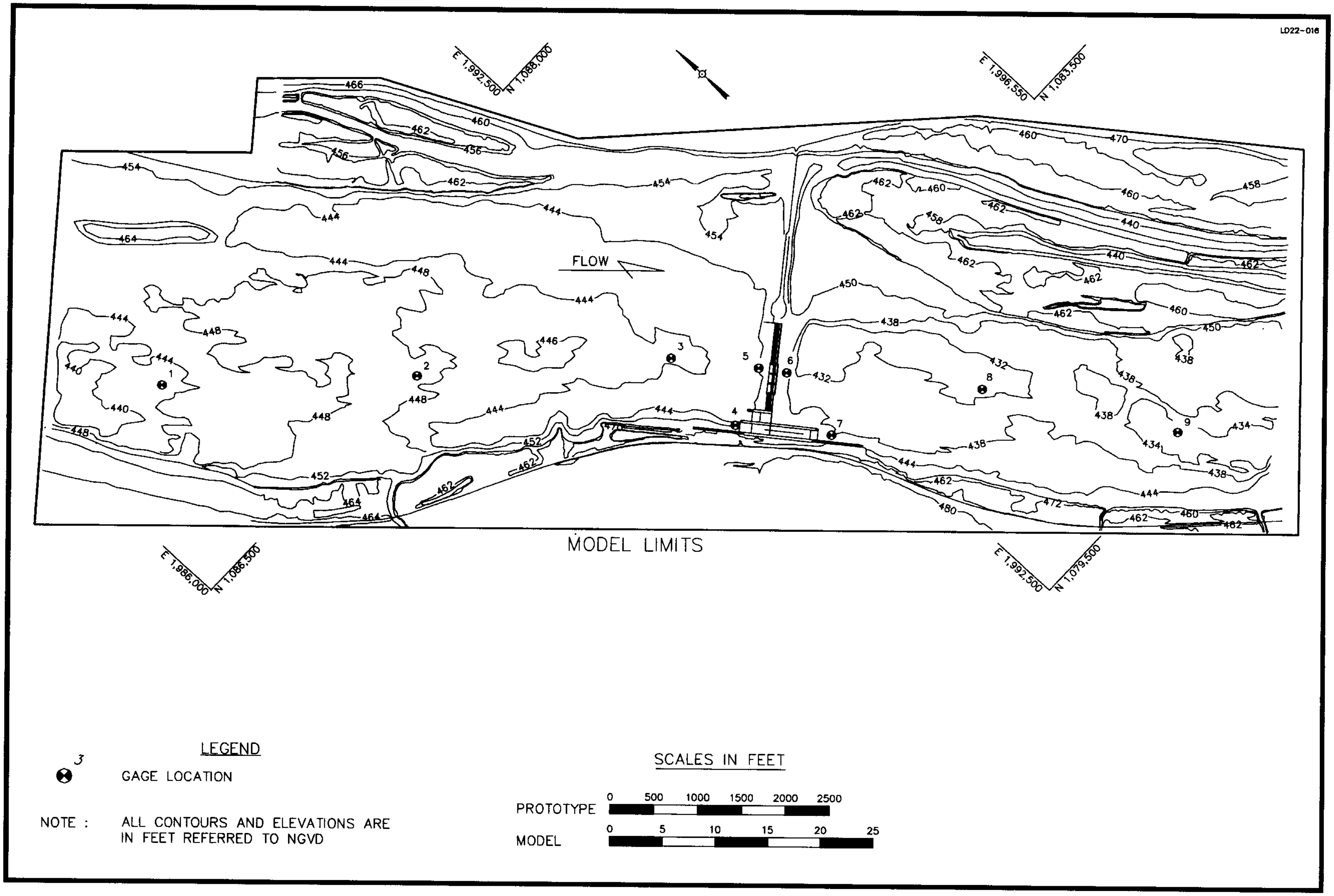


Figure 2. Model layout and location of gauges

Measurements of discharges, water-surface elevations, and current velocities can be transferred quantitatively from model to prototype by these scale relations.

Appurtenances

Water was supplied to the model by a 10-cfs pump operating in a recirculating system. The discharge was controlled and measured by a valve and a venturi meter. Water-surface elevations were measured by piezometer gauges located in the model channel and connected to a centrally located gauge pit (Figure 2). For controlled riverflows, upper pool stages were controlled at the dam by opening and closing the dam slide gates; for open riverflows, tailwater elevations were controlled by a tailgate located at the lower end of the model.

Model Adjustment

The surface of the model was constructed of brushed cement mortar to provide a roughness (Manning's n) of about 0.0135, which corresponds to a roughness in the prototype of about 0.030. With the existing lock and dam in place, the model was checked against available prototype data and the constant discharge design tailwater and headwater rating curves. The results indicated that the model reproduced conditions in the prototype with a reasonable degree of accuracy based on the available data.

Information provided by the time-lapse video recorder and camera installed at the project from December 1993 to October 1994 to record the path and maneuvering required for tows to enter and leave the upper lock approach (Photos 1-4) was then compared with model data taken with model tows entering and leaving the upper lock approaches with various riverflows. This comparison indicated that the model reproduced prototype navigation conditions that exist at the project with a reasonable degree of accuracy.

3 Experiments and Results

Experiment Procedures

The primary concerns of the experiments were to study flow patterns, measure velocities and water-surface elevations, assess the effects of currents on the movement of the model tow approaching and leaving the existing lock, and determine how the placement of a new 1,200-ft lock would affect current patterns in the lock approaches. These conditions were studied with the existing 600-ft lock and with four proposals for positioning of the 1,200-ft lock. The four plans for placement of the 1,200-ft lock are as follows:

a. Location 1: Adding a 1,200-ft lock landward of the existing 600-ft lock.

b. Location 2: Extending the existing 600-ft chamber to provide a 1,200-ft chamber.

c. Location 3: Adding a 1,200-ft lock at the auxiliary lock chamber.

d. Location 4: Adding a 1,200-ft lock riverward of the auxiliary lock by removing two gate bays.

The riverflows were reproduced by introducing the proper discharge and manipulating the tailgate until the required tailwater elevation was obtained. During controlled pool flow conditions, the upper pool was maintained by adjusting the gates of the dam, maintaining a uniform opening for all gates. During open river flows, all of the dam gates were removed. During Base Experiments, the upper pool elevation was controlled at Gauge 4 to settings supplied by the U.S. Army Engineer District, Rock Island, and the lower pool elevation was controlled at Gauge 7 (Figure 2). For subsequent experiments the tailwater was controlled at Gauge 9 to elevations obtained during the Base Experiment.

A selection of representative flows were used for evaluation based on information furnished by the Rock Island District as shown in the following tabulation:

Riverflow, cfs	Tailwater El
50,000 (controlled pool)	451.3
100,000 (controlled pool)	454.7
162,000 (open river)	459.5
220,000	462.8
276,000 (maximum navigable)	466.1

Current directions were determined by tracking the paths of lighted floats with respect to ranges established for that purpose with the video camera tracking system mounted over the model. The floats were weighted to simulate the maximum draft for loaded barges using the waterway (9-ft prototype). Velocities were measured using a desktop computer that calculated velocity based on the time required by floats to pass over a measured distance. This method provided detailed information on the currents that would affect tows moving through the reach. For clarity, in plots of currents in turbulent areas or where eddies or crosscurrents existed, only the main trends are shown. Confetti was also used to determine surface current patterns. Dye was also introduced in the model to illustrate the current patterns, which were recorded with time-lapse photography.

A radio-controlled model towboat and barges were used to evaluate and demonstrate the effects of currents on tows approaching and leaving the lock and in the critical reaches of the project. The towboat was equipped with twin screws, Kort nozzles, and forward and reverse rudders and powered by a small electric motor operating from batteries in the tow. The speed and rudders of the tow were remote-controlled, and the towboat could be operated in forward and reverse at speeds comparable to those that could be expected to be used by the towboats on the Upper Mississippi River waterway. The tow used in the study represented a makeup of fifteen 195-ft-long by 35-ft-wide standard barges with a 150-ft-long pusher. This provided a overall size tow of 1,125 ft long by 105 ft wide loaded to a draft of 9 ft. The model towboat provides an accurate representation of the maneuvering characteristics of prototype towboats. The speed of the towboat was calibrated in slack water to simulate the speed of a comparable size prototype towboat. The model tow was operated at 1 to 2 mph above the speed of the currents to maintain rudder control but not overpower the currents. Multiple-exposure time-lapse photography was used to record the path of the model tow navigating the reach. The video tracking system was also used to track the model tow for evaluation of navigation conditions and for recording approach times for downbound tows approaching the lock with the various plans.

Base Experiments (Existing Conditions)

Description

Base experiments were conducted with the model reproducing existing conditions as shown in Figure 3. The purposes of the experiments were to verify that the model was reproducing kown prototype conditions and to provide information and data that could be used to evaluate the effect of the proposed modifications on water-surface elevations, current direction and velocities, and navigation conditions. The maneuvering required for the model tow to navigate the reach with various riverflows was compared to the field data of tows navigating the reach with similar riverflows. This comparision indicated that the model was accurately simulating the effect of currents on tows entering and leaving the lock approaches. The principal features reproduced or simulated in the model, shown in Figures 3 and 4 and Photo 5, included the following:

a. A lock with clear chamber dimensions of 110 ft wide by 600 ft long located along the right descending bank at about river mile 301.2, a 571-ft-long upper guide wall, a 571-ft-long lower guide wall, and provisions for a second lock on the riverward side. The top of lock walls were at el 471.5.

b A 1,000-ft-long rock dike extended upstream from the upstream end of the upper guide wall. The center line of the rock dike was offset landward to provide navigation depth for tows aligned with the guide wall.

c. An auxiliary lock adjacent to the navigation lock that has only the upper miter gate and no usable chamber.

d. A 1,024-ft nonnavigable gated spillway including ten 60- by 25-ft tainter gates and three 100- by 25-ft roller gates with sill el 434.5. The dam was connected to high ground on the left overbank with an earth dike, top el 459.5.

Results

Water-surface elevations. Water-surface elevations obtained with existing conditions (Table 1) indicate the average slope in the model upstream of the dam (Gauges 1-5) ranged from less than 0.1 to about 0.8 ft per mile and downstream of the dam (Gauges 6-9), from about 0.1 to 0.4 ft per mile with riverflows of 50,000 and 162,000 cfs, respectively. The drop across the gated dam (Gauges 5 and 6) with open riverflows was about 0.4 ft.

Current directions and velocities. Data shown in Plates 1-5 indicated that the currents upstream of the dam were generally parallel to the right bank from the upstream model limit until reaching the upstream end of the stone dike along the right bank about 2,500 ft upstream of the dam. The flow then tended to

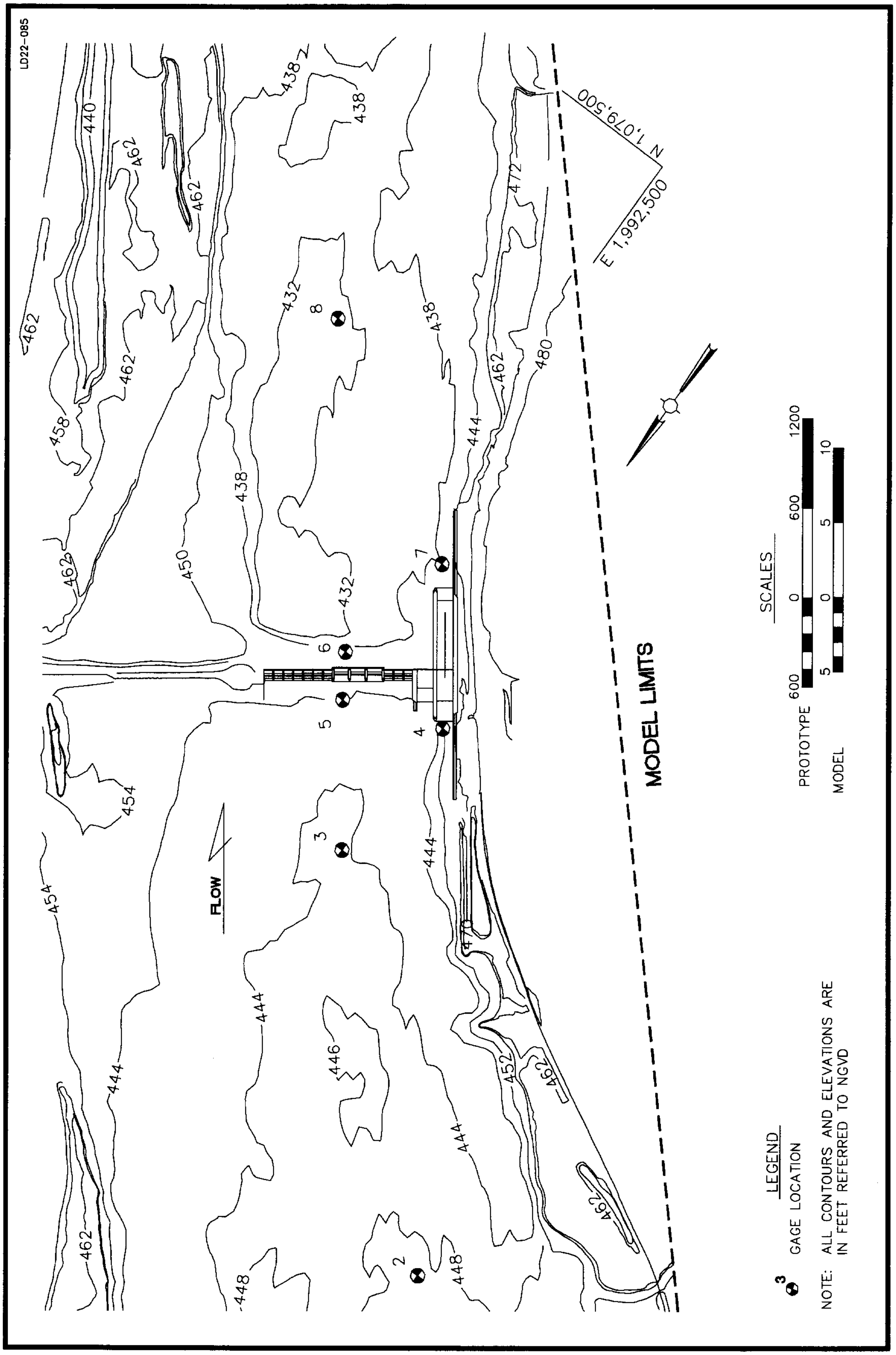


Figure 3. Existing conditions

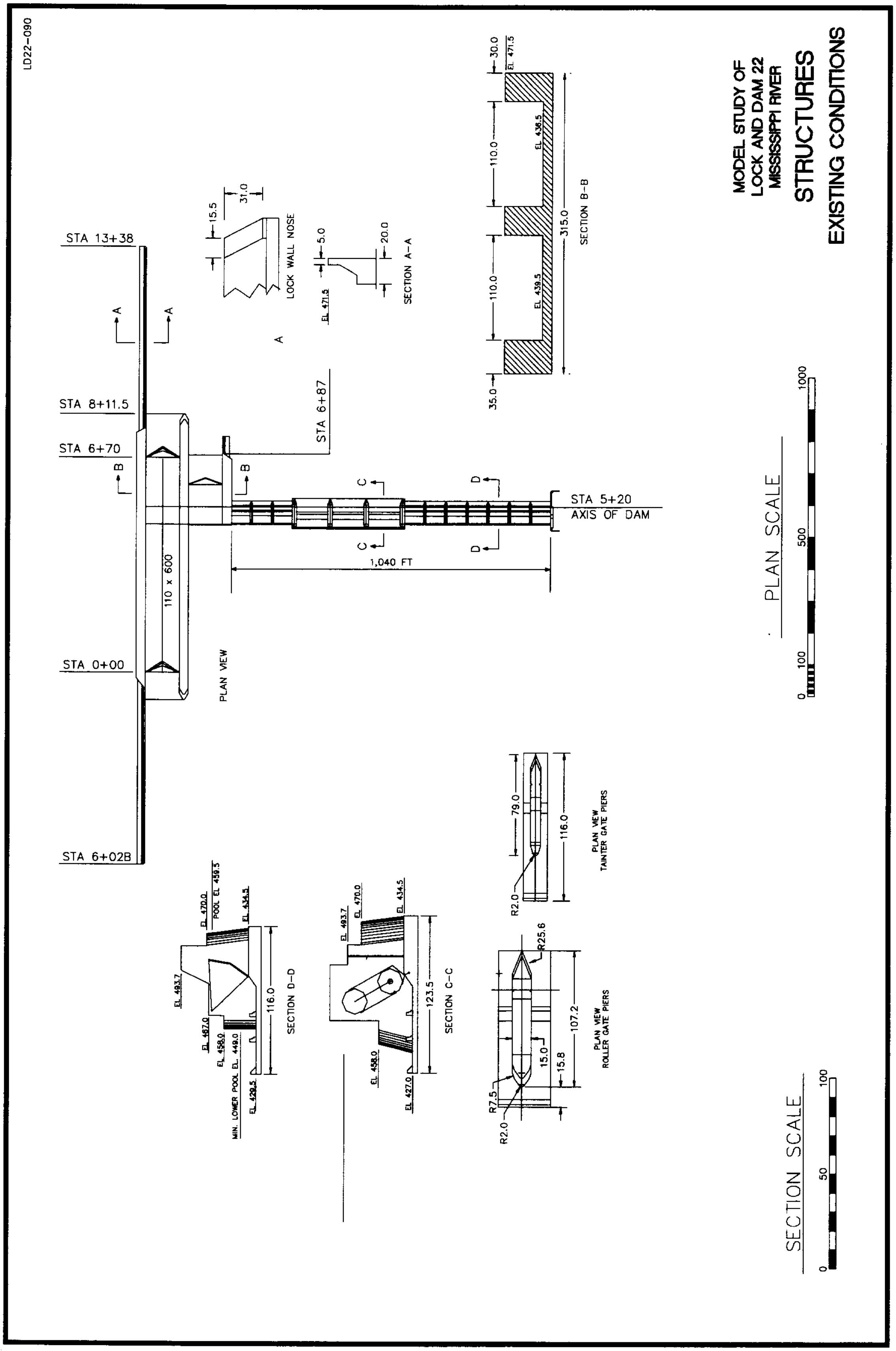


Figure 4. General plan and sections, existing structures

move across the upper lock approach toward the dam creating a strong outdraft (Photo 6). With the lower riverflows a clockwise eddy formed in the upper lock approach that would tend to push the head of a tow away from the guide wall. As the discharge increased and the strength of the crosscurrents increased, the size of the eddy decreased and at some point ceased to exist. The currents downstream of the dam tended to move across the lower lock approach toward the right bank and then parallel the right bank through the modeled reach. The maximum velocity of the currents in the navigation channel upstream of the lock varied from about 2.0 to 6.6 fps approximately 8,000 ft upstream of the dam, 2.0 to 6.0 fps about 3,000 ft upstream of the dam where tows start flanking the stern of the tow toward the stone dike, and 1.1 to 5.6 fps near the upstream end of the guide wall with the 50,000- and 276,000-cfs flows, respectively. The maximum velocity of the currents moving across the lower lock approach varied from 2.5 to 5.6 fps with the 50,000- and 276,000-cfs riverflows, respectively. The velocity of the currents in the navigation channel about 5,000 ft downstream of the dam varied from about 2.2 to 6.6 fps with the 50,000- and 276,000-cfs riverflow, respectively.

Navigation conditions. Due to the alignment of the right bank upstream of the lock relative to the upper guide wall and the set of the currents moving across the upper approach of the lock, navigation conditions for downbound tows were extremely difficult even with the lower riverflows and could be hazardous under some conditions. Field data show that a helper towboat is used by downbound towboats to push their tows into the guide wall with most flow conditions. Downbound tows approach the upper guide wall by flanking the stern of the towboat in close to the rock dike running along the right bank, bringing the tow to a complete stop with the head of the tow swinging riverward (Photo 1), and allowing the helper towboat to push the head of the tow into the guide wall (Photos 2 and 3). The helper towboat holds the tow close to the guide wall as the tow moves into the lock chamber. Experiments made with the model tow show the same maneuvers were required for a downbound tow approaching the 600-ft lock (Photo 7). Upbound tows leaving the lock tend to be moved riverward as they leave the lock approach, and tows take a set toward the right descending bank to overcome the currents (Photo 4). However, no major difficulties were indicated for tows with sufficient power and steerage to overcome the currents. Experiments made with the model tow show the same maneuver was required for an upbound tow leaving the 600-ft lock (Photo 8).

Due to the lock being located on the convex side of a bend, downbound tows leaving the lock rotate the head of the tow riverward as the tow moves along the guide wall to counteract the currents moving across the lower lock approach (Photo 9). No serious difficulties were indicated for tows with sufficient power and steerage to overcome the currents. However, upbound tows approach the lower guide wall with a riverward set to counteract the currents and let the head of the tow move into the guide wall as the tow approaches the lock chamber. There is a guard cell located immediately downstream of the center wall of the lock to protect the lock wall. Some maneuvering is required at some riverflows for the tow to align with the guide wall and enter the lock chamber (Photo 10).

Lock Location 1

The lock at Dam 22 is located along the right bank adjacent to steeply rising terrain. Landward of the lock is a railroad and State Highway 79. Rock Island District reviewed the topography at Dam 22 and decided it was not feasible to construct a new lock at Location 1. Therefore, no model experiments were conducted with the model simulating a new lock at Location 1.

Lock Location 2, Plan A

Description

This plan involved extending the existing 600-ft chamber to provide a lock chamber with clear dimensions of 110 ft wide by 1,200 ft long. A 1,200-ft-long solid landside guide wall was added to the downstream end of the new 1,200-ft lock chamber, and a 1,200-ft-long ported guard wall was added to the upstream end of the center lock wall. The solid upper guide wall for the existing 600-ft lock chamber and the stone dike along the right bank were removed, and the bank line was excavated and reshaped to provide a 200-ft-wide navigation channel at the upstream end of the guard wall. The 1V on 3H slope was extended up to el 470 with a 20-ft-wide berm and a 1V on 3H slope on the landside of the berm. The berm extended upstream to a point about 2,400 ft upstream of the axis of the dam. The entrance channel along the length of the upper guard wall was graded to el 438 with the excavation extending 50 ft riverward of the guard wall.

The principal features of Lock Location 2, Plan A, were as follows (Figures 5 and 6):

a. A 110-ft-wide by 1,200-ft-long lock chamber replacing the existing lock chamber.

b. A 1,200-ft-long ported upper guard wall with twenty-two 30-ft-diameter cells spaced 50 ft on centers and a 50-ft-diameter guard cell at the upstream end of the wall. This provided twenty-two 20-ft-wide port openings and one 40-ft-wide port opening with the top of ports at el 448.5 (11 ft below normal pool of 459.5). The effective length of the guard wall measured from the upstream end of the landside lock wall to the upstream end of the guard wall was 1,200 ft and would provide protection for the design size tow.

c. A 1,200-ft-long solid lower guide wall extending downstream from the land side lock wall.

d. Modification of the upper lock approach by removing the existing upper guide wall and the stone dike along the right bank by excavating and

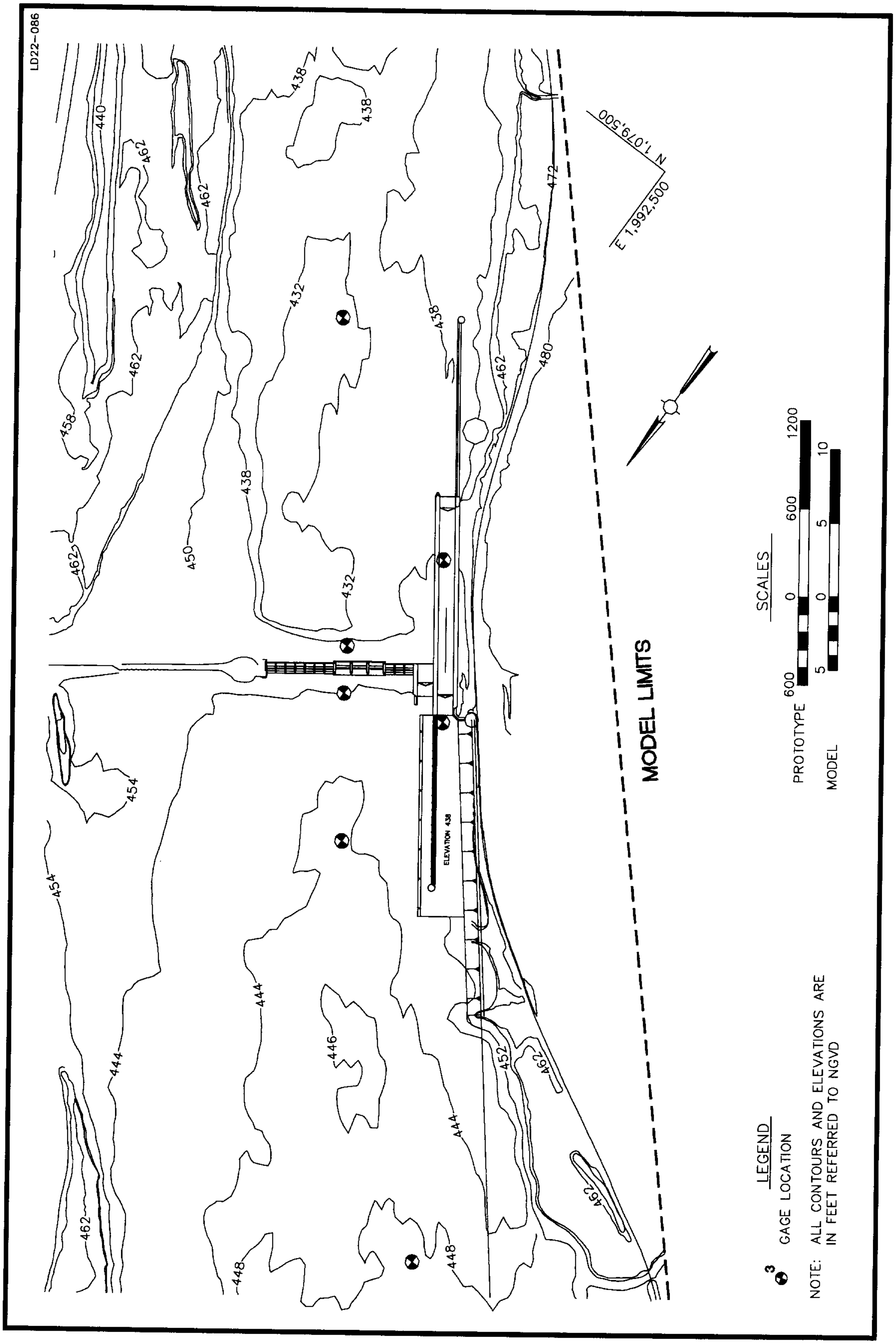


Figure 5. Lock Location 2, Plan A

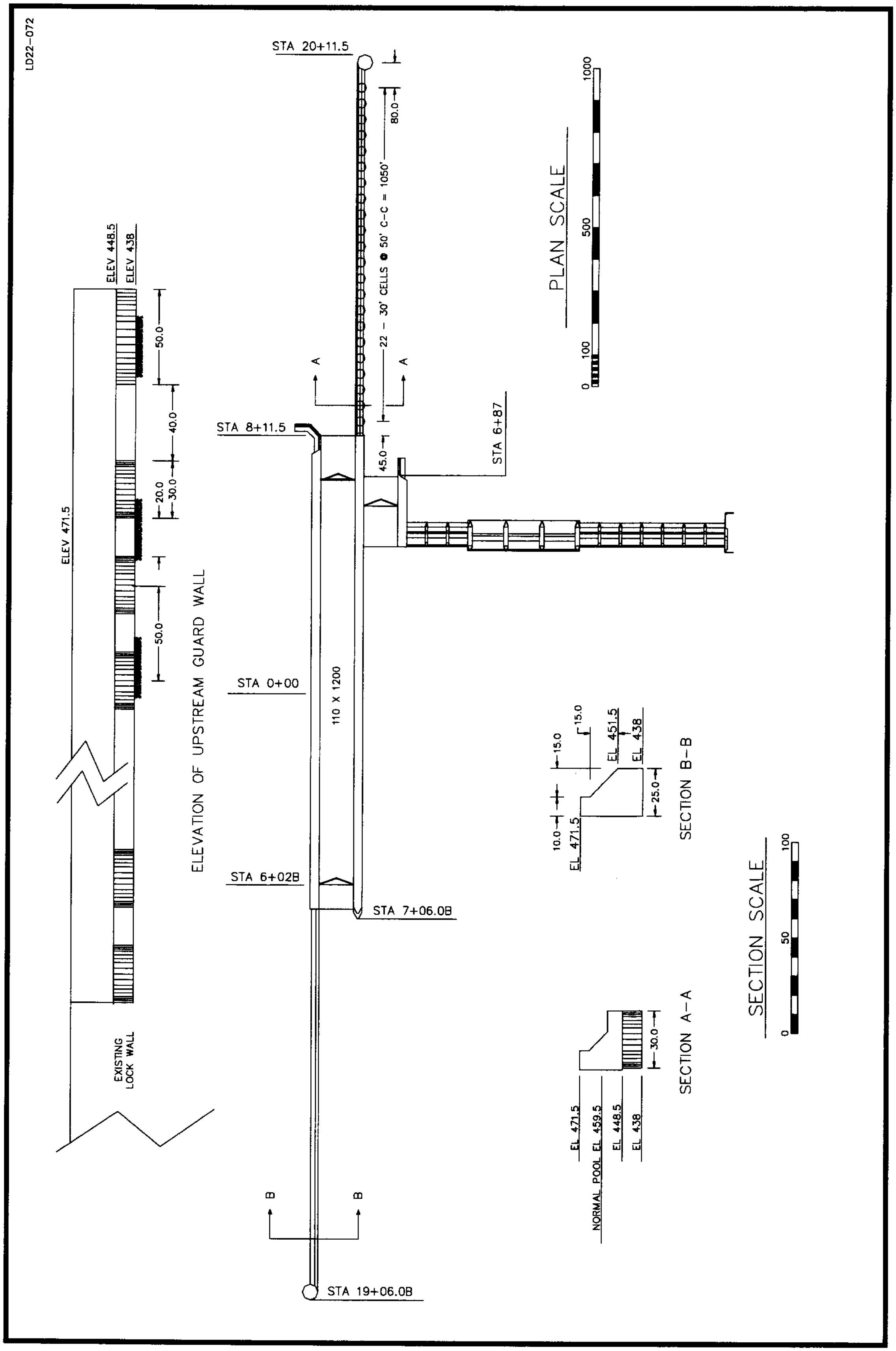


Figure 6. General plan and sections, Lock Location 2

reshaping the bank line to provide a 200-ft-wide entrance at the upstream end of the guard wall. The 1V on 3H slope was extended up to el 470 with a 20-ft-wide berm and a 1V on 3H slope on the landside of the berm. The berm extended upstream to connect with the right bank spur dike about 2,400 ft upstream of the axis of the dam. The entrance channel along the length of the upper guard wall was graded to el 438 with the excavation extending 50 ft riverward of the guard wall.

Results

The model experiments were conducted using the same operating procedures and flow conditions as those used for Base Experiments.

Water-surface elevations. Elevations shown in Table 2 indicate that water-surface elevations were generally about the same as those measured during the Base Experiment conditions (Table 1).

Current directions and velocities. Current direction and velocity data shown in Plates 6-10 indicate that the currents upstream of the dam were generally parallel to the right bank from the upstream model limits until reaching the right bank spur dike approximately 3,000 ft upstream of the axis of the dam. Then the currents moved across the upper approach of the lock and around the upstream end of the guard wall. Only with a riverflow of 100,000 cfs was there a tendency for the currents to enter the upper lock approach parallel to the guard wall (Plate 7). Currents downstream of the dam generally moved parallel to the lock to the downstream end of the lock and then turned toward the right bank and moved across the lower lock approach. The maximum velocity in the navigation channel upstream of the lock varied from 1.6 to 5.0 fps about 6,000 ft upstream of the axis of the dam and from 1.8 to 6.1 fps about 3,000 ft upstream of the axis of the dam with the 50,000- and 276,000-cfs flows, respectively. The maximum velocities in the navigation channel downstream of the dam varied from 2.7 to 6.1 fps near the downstream end of the lower guide wall to 3.1 to 6.6 fps about 6,000 ft downstream of the axis of the dam with the 50,000- and 276,000-cfs flows, respectively.

Navigation conditions. Navigation conditions were unsatisfactory for downbound tows approaching the new 1,200-ft chamber. With a riverflow of 50,000 cfs, a downbound tow could align with the upper guard wall about four tow lengths upstream of the upstream end of the guard wall, start reducing speed about two tow lengths upstream of the guard wall, and enter the lock approach at a slow speed (Photo 11). However, as the tow approached the upstream end of the right bank realignment, currents moving across the approach channel from the right bank area moved the tow riverward with a possibility of the tow being moved riverward of the guard wall. As the riverflow increased and the magnitude of the currents moving across the approach increased, downbound tows were moved into or riverward of the guard wall (Photo 12). Considerable maneuvering and power would be required for a tow to avoid striking the upstream end of the guard wall or being moved riverward of the wall. Navigation conditions could be hazardous under most conditions. The distance between the upstream end of the guard wall and the upstream end of the realigned bank did not allow sufficient maneuvering area for a towboat to swing the head of the tow inside the guard wall. When the head of the tow was near the upstream end of the guard wall, the stern of the tow was exposed to currents moving across the upper approach. Adding the guard wall reduced the length of protected area available for a towboat to maneuver the head of the tow and made it hazardous for a helper towboat to push the head of the tow toward the land side of the guard wall. Navigation conditions were worse than with existing conditions due to less protected area for maneuvering. With existing conditions, the full length of a 1,200-ft tow was protected from crosscurrents, allowing the towboat to control the stern of the tow while a helper towboat controlled the head of the tow. Downbound tows could not enter the upper lock approach at a safe speed.

Upbound tows could leave the upper lock approach without any major difficulties. However, as the tow moved upstream of the right bank realignment, it was required to take a landward set to counteract the currents moving across the navigation channel (Photo 13).

Navigation conditions were satisfactory for tows entering and leaving the lower lock approach with all riverflows evaluated. Downbound tows could rotate the head of the tow away from the guide wall and navigate downstream without any difficulties (Photo 14). Upbound tows could approach the lock from midchannel, align with the guide wall, and enter the lock chamber with a minimum of maneuvering (Photo 15).

Lock Location 2, Plan B

Description

Lock Location 2, Plan B, was the same as Plan A except that a system of five spur dikes was constructed along the right descending bank upstream of the dam to train currents along the right bank (Figure 7 and Photo 16). The river ends of the dikes were aligned with the 20-ft berm running along the top bank of the upper lock approach. This provided approximately 8,000 ft of straight navigation channel approaching the lock. The spacing between the dikes at the river end was about 1,000 ft. The first dike was located 3,251 ft upstream of the axis of the dam and had a 250-ft-long trail dike extending downstream from its river end running parallel with the navigation channel (L-head dike). The dikes were added to align the flow parallel with the upper guard wall and away from the right bank. The NAD 83 State Plane Coordinates for the dike are listed in the following tabulation:

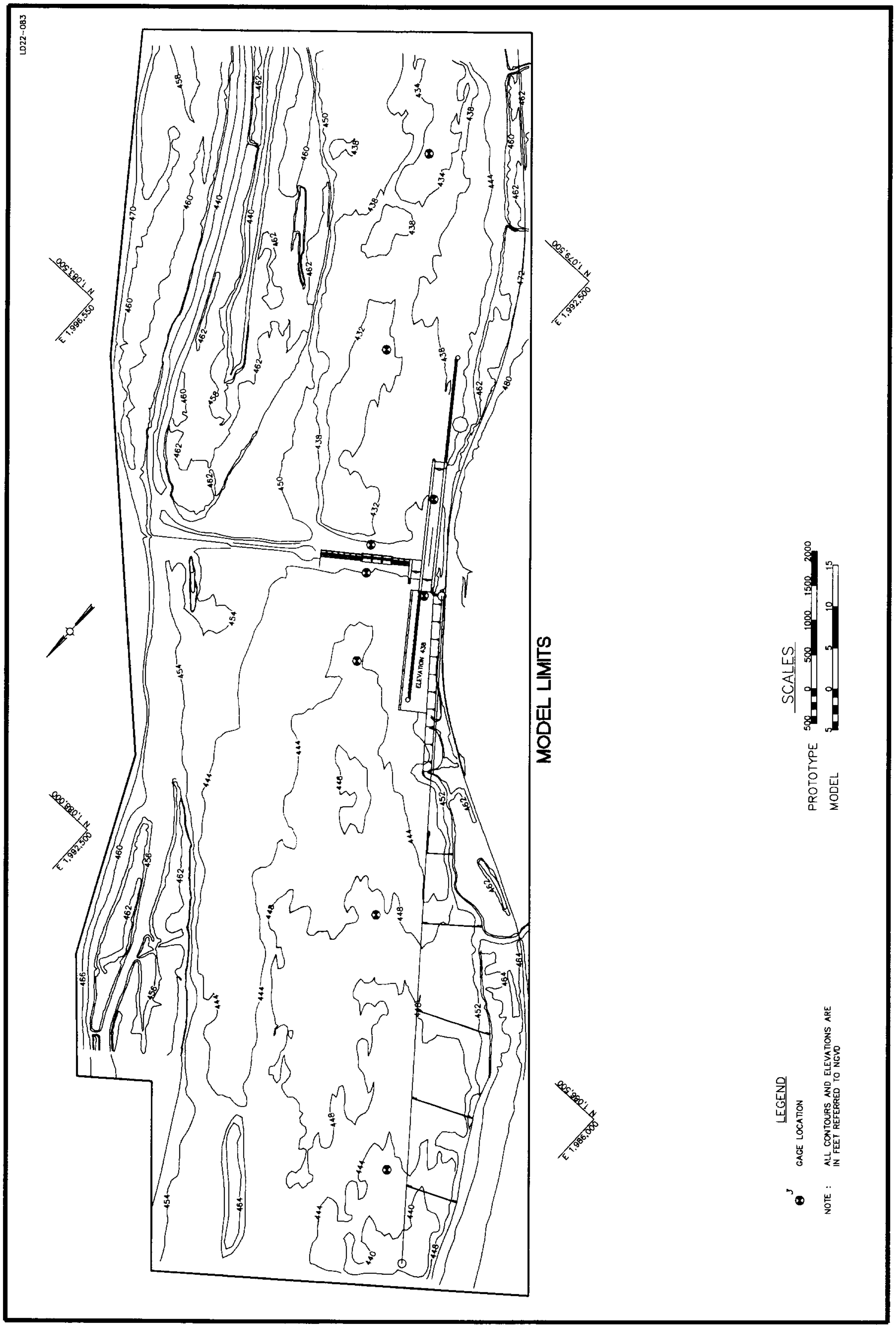


Figure 7. Lock Location 2, Plan B

Dikes Numbered from Lock Upstream	North Coordinate River End	East Coordinate River End	Azimuth of Alignment
1 (L-head dike)	N 1,085,552	E 1,989,457	230°53'23"
2	N 1,086,179	E 1,988,960	230°53'23"
3	N 1,086,955	E 1,988,329	245°53'23"
4	N 1,087,731	E 1,987,698	245°53'23"
5	N 1,088,507	E 1,987,067	245°53'23"
Note: All dikes tied into higher ground at el 461.5.			

Results

The model experiments were conducted using the same operating procedures and flow conditions as those used for Base Experiments.

Water-surface elevations. Water-surface elevations shown in Table 3 indicate that the dike system increased water-surface elevations upstream of the dam. The increase in water-surface elevations ranged from 0.1 to 0.4 ft with the 276,000- and 50,000-cfs riverflows, respectively. The largest increase in water-surface elevations occurred with controlled riverflows when the total flow was confined by the dike system. As the elevation of the upper pool increased and flow started overtopping the dikes, the increase in water-surface elevations was not as much as with existing conditions. Scouring would probably occur riverward of the dikes, reducing the water-surface level.

Current directions and velocities. Current direction and velocity data shown in Plates 11-15 indicate that the currents generally moved parallel with the right bank dike system from the upper end of the model into the upper lock approach with all riverflows evaluated. However, the dike system also increased the velocity of the current slightly through this reach. The currents entered the upper lock approach parallel to the ported guard wall with very little outdraft near the upper end of the wall. The flow was uniformly distributed through the guard wall ports, providing excellent conditions for tows approaching the wall. The maximum velocity of the currents in the navigation channel approaching the new lock varied from 2.7 to 6.2 fps about 8,000 ft upstream of the axis of the dam (opposite the most upstream dike), about 1.8 to 5.9 fps about 5,000 ft upstream of the axis of the dam, and about 1.3 to 5.1 fps approaching the upstream end of the guard wall with the 50,000- and 220,000-cfs riverflows, respectively. Currents downstream of the dam were generally the same as with Plan A.

Navigation conditions. Navigation conditions for tows entering and leaving the upper lock approach were greatly improved by adding the system of dikes along the right descending bank. Downbound tows could navigate 50 to 100 ft riverward of the river end of the dikes, align with the guard wall three to four tow lengths upstream of the wall, start reducing speed, and enter the lock approach at a slow speed (Photo 17). As the tow entered the lock approach, currents moving toward and through the guard wall assisted the tow by slowly moving the tow toward the guard wall and aligning it with the lock chamber. With the higher riverflows, the river ends of the dikes were too close to the normal path of a downbound tow approaching the lock, and the currents near the ends of the dikes tended to move the tow riverward of a ideal alignment for the lock approach. Therefore, a downbound tow was required to take a set toward the dikes to counteract the currents until it reach the vicinity of the L-head dike where it could align with the guard wall and start reducing speed (Photo 18). Upbound tows could move away from the guard wall, push straight out of the approach, and proceed upstream 100 to 200 ft riverward of the dike system without any difficulties (Photo 19).

Recommendations for future experiments

If this location is selected as the recommended location, additional experiments should be conducted to improve navigation conditions at the site. The length of the dikes along the right descending bank should be optimized by shortening the dikes. The river end of the dikes should allow a downbound tow to align with the upper lock approach while staying 100 to 200 ft riverward of the dikes.

Lock Location 3, Plan A

Description

Lock Location 3, Plan A, involved replacing the existing auxiliary lock with a new lock chamber with clear dimensions of 110 by 1,200 ft or adding to the existing structure. The upstream miter gate of the auxiliary lock would serve as the upstream miter gate of the new lock.

The principal features, shown in Figures 8 and 9, were as follows:

a. Addition of a 110- by 1,200-ft lock chamber incorporating the auxiliary lock adjacent to the existing lock.

b. A 1,320-ft-long ported guard wall with twenty-four 30-ft-diameter cells spaced 50 ft on centers and a 50-ft guard cell at the upper end of the wall. This provided twenty-three 20-ft-wide port openings and one 40-ft-wide port opening with the top of ports at el 448.5 (11 ft below normal pool of 459.5). The effective length of the guard wall measured from the upstream end of the center wall to the upstream end of the guard wall was 1,200 ft and provided full protection for the design size tow.

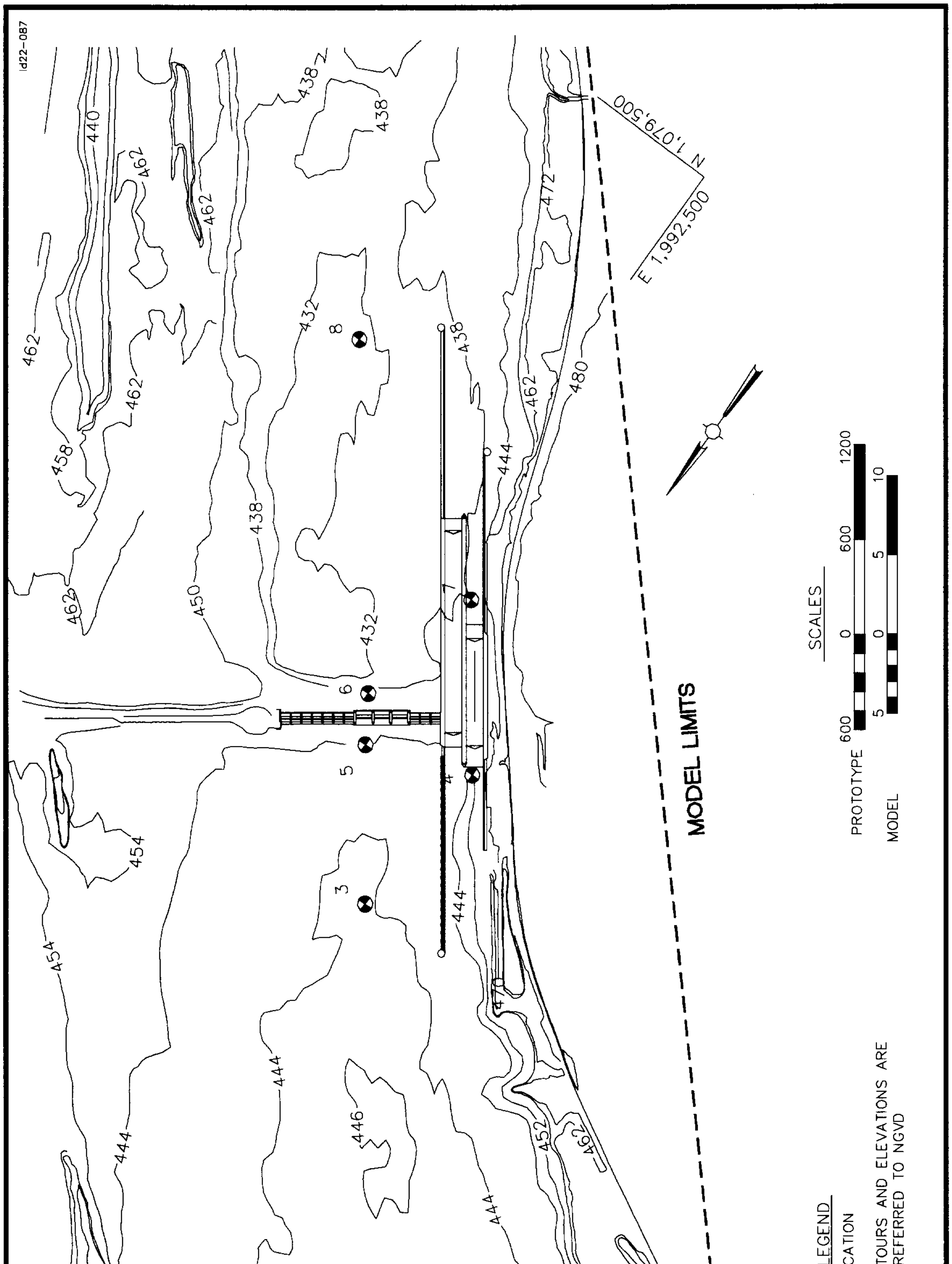


Figure 8. Lock Location 3, Plan A

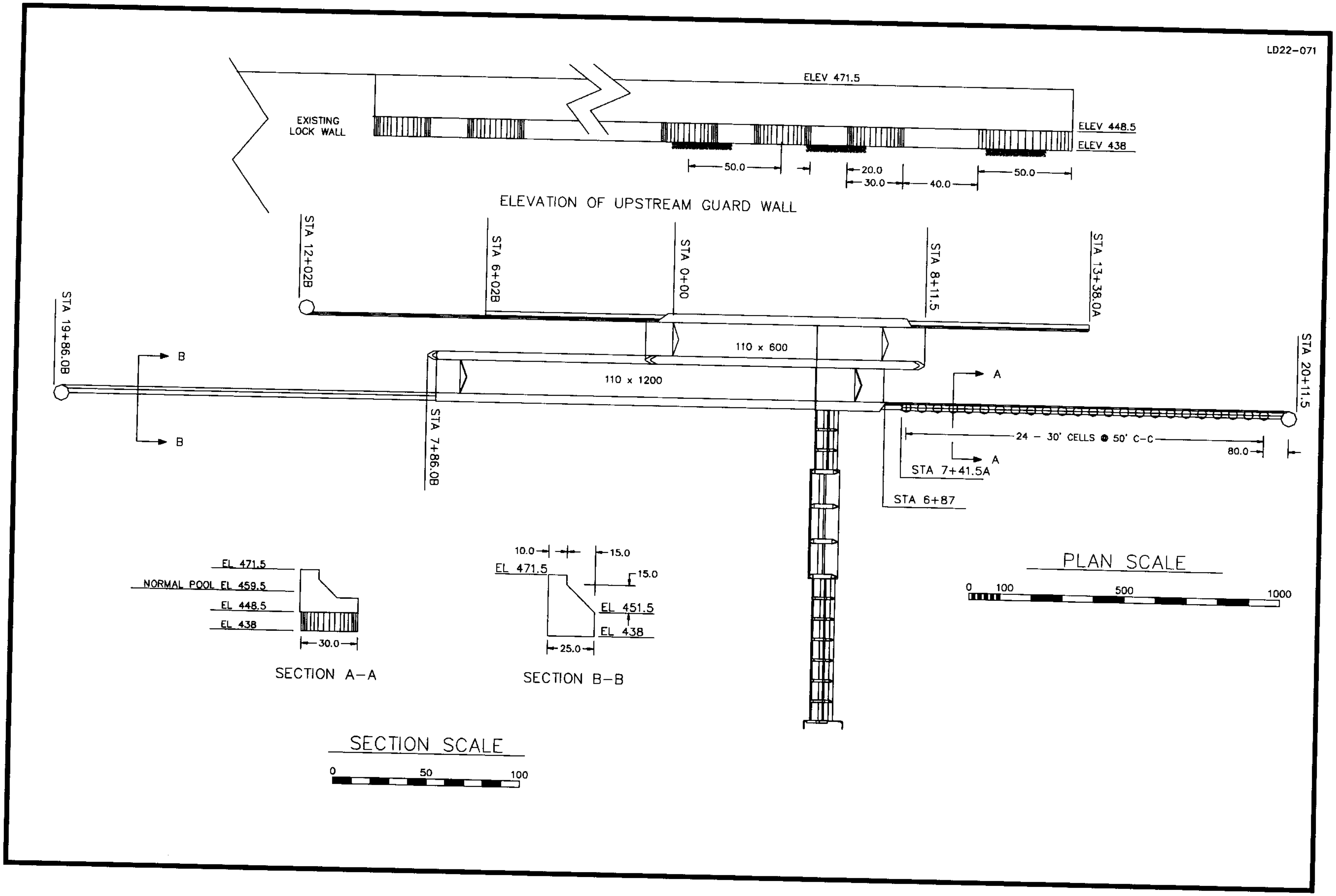


Figure 9. General plan and sections, Lock Location 3, Plan A

c. A 1,200-ft-long solid lower guard wall extending downstream from the riverside lock wall.

d. A 600-ft-long extension added to the downstream end of the landside guide wall of the 600-ft lock. This provided 416.0 ft of usable length of guide wall (measured from the downstream end of the center lock wall to the downstream end of the guide wall extension) for tows using the existing 600-ft lock.

Results

The model experiments were conducted using the same operating procedures for the dam and flow conditions as those used for Base Experiments.

Water-surface elevations. Water-surface elevations shown in Table 4 indicate that the average slope of the water surface through the reach was generally the same as in the Base Experiments. With uncontrolled riverflows of 162,000 cfs and above, Gauge 4, in the upper lock approach, shows a slight increase in water-surface elevation. This can be attributed to the tendency for a head differential to build inside a riverside guard wall. This tendency is also reflected with the 100,000-cfs controlled riverflow, which was controlled at Gauge 4. This resulted in the water-surface elevation upstream of Gauge 4 being about 0.2 ft lower than those measured with Base Experiments. Water-surface elevations downstream increased slightly in the vicinity of the new 1,200-ft lock. The largest increase of 0.3 ft occurred at Gauge 7 with the 162,000-cfs riverflow. This can be attributed to Gauge 7 being located in the lower approach of the existing 600-ft lock; due to its location, it measured water-surface elevations influenced by the downstream end of the new 1,200-ft guide wall.

Current directions and velocities. Currents upstream of the dam were generally the same as those of Base Experiments from the upstream end of the model to the upstream end of the right bank longitudinal dike where the new guard wall started influencing the currents. Current direction and velocity data shown in Plates 16-20 indicate that the currents generally moved parallel to the right descending bank until reaching the upstream end of the existing longitudinal dike and then moved across the upper lock approach. The new ported guard wall intercepted some of the flow moving across the upper lock approach toward the dam. There were some currents moving around the upper end of the guard wall due to the alignment of the currents approaching the wall. The flow that was intercepted by the guard wall was distributed along the wall and moved through submerged ports of the wall. There was more flow through the ports along the upper end of the wall due to the alignment of the currents approaching the wall. The currents downstream of the dam moved parallel to the new lock from the dam to the downstream end of the new guard wall, then turned toward the right bank, moving across the approach to the new lock. A low-velocity clockwise eddy formed along the right bank downstream of the lock and extended upstream into the lower approach of the lock. The maximum velocity of the currents in the navigation channel upstream of the lock varied from about

1.7 to 4.8 fps 6,000 ft upstream of the axis of the dam and from about 2.0 to 5.3 fps near the upstream end of the upper guard wall for riverflows of 50,000 and 276,000 cfs, respectively. The maximum velocity in the navigation channel downstream of the lock varied from about 3.1 to 6.9 fps near the downstream end of the lower guard wall with the 50,000- and 220,000-cfs riverflows, respectively, and from about 2.5 to 6.7 fps about 3,000 ft downstream of the lock for riverflows of 50,000 and 276,000 cfs, respectively.

Navigation conditions. Navigation conditions were improved for tows entering and leaving the upper lock approach with all riverflows evaluated compared with Base Experiments. With the 50,000-cfs riverflow, downbound tows could drive toward the upper lock approach, align with the guard wall about three tow lengths upstream of the wall, start reducing speed, and enter the lock approach at a slow speed (Photo 20). As the tow approached the upper end of the right bank longitudinal dike, the flow moving from the right bank toward the dam started moving the tow toward the dam and out of alignment with the approach. However, the velocity of the currents was low, and the tow was able to control its alignment with a minimum of maneuvering and enter the approach without any major difficulties. As the riverflow increased, a downbound tow was required to take a set toward the right descending bank to counteract the flow along the right bank as it approached the lock (Photo 21). Although a downbound tow could align with the upper guard wall and enter the upper approach at a slow speed, any error in alignment could result in the tow being required to stop and flank toward the right bank to align with the approach before entering it. This maneuver could require considerable time, and cautious pilots may use this maneuver during most of the downbound approaches. As the riverflow increased above 162,000 cfs, downbound tows were required to drive as close along the right bank as channel depth allowed, start flanking about three tow lengths upstream of the upper end of the guard wall, reduce speed while holding the stern of the tow into the right bank, ease the tow down the right bank, and swing the head of the tow landward of the guard wall (Photo 22). This maneuver was very difficult, and any error in judgment or alignment could have resulted in the tow striking the upper end of the guard wall or being moved around the upper end of the wall. Upbound tows could move away from the guard wall, take a set toward the right bank to counteract the currents moving toward the dam, and exit the approach without any major difficulties (Photo 23). As the tow moved upstream, it was required take a greater set toward the right bank to counteract the currents, similar to Base Experiments with existing conditions.

Tows could enter and leave the lower lock approach without any major difficulties with all riverflows evaluated. Downbound tows could move away from the lower guard wall, turn riverward, and move toward midchannel (Photo 24). However, due to the alignment of the currents immediately downstream of the guard wall and the turn required for the tow to enter the existing navigation channel, the stern of the tow swung close to the right bank. Some additional channel excavation may be required to provide adequate navigation depth. Upbound tows could navigate along the existing navigation channel to a point about two tow lengths downstream of the guard wall, start moving toward the right bank and taking a set toward the left bank to counteract the current moving around the lower end of the guard wall, and enter the lock approach without any major difficulties (Photo 25). As the tow entered the protection of the guard wall, the clockwise eddy that formed along the right bank necessitated some maneuvering by the tow. The tow started maneuvering to approach the guard wall by flanking to reduce speed and to counteract the rotation of the eddy. With the higher riverflows and faster eddy velocities, considerable maneuvering can be required for the tow to align with the wall and push into the lock chamber.

Recommendations for future experiments

If this location is selected as the recommended location, additional experiments should be conducted to improve navigation conditions at the site. Some of the recommended experiments are as follows:

a. A system of dikes similar to those in Plan B should be developed to improve navigation conditions for tows entering and leaving the upper lock approach. The length of the dikes may be slightly different from those developed in Plan B.

b. A 50- to 75-ft-long wing wall angled 10 to 15 degrees off the lower riverside lock wall could aid a tow approaching the lock chamber by guiding the head of the tow into the guard wall.

c. Realignment of the right descending bank immediately downstream of the lock may reduce the size and intensity of the eddy that forms between the new guard wall and the right bank. This could reduce the maneuvering required for a tow to approach the lock and align with the guard wall.

d. Moving the riverside 1,200-ft-long solid lower guard wall to the landside lower lock wall may improve navigation conditions for tows entering and leaving the new 1,200-ft lock. However, a landside guide wall could restrict the use of the existing 600-ft-long lock.

Lock Location 4, Plan A

Description

Lock Location 4, Plan A, involved adding a new lock with clear dimensions of 110 by 1,200 ft riverward of the existing auxiliary lock. The upper gate pintle of the new lock was located at sta 5+90A, or about 70 ft upstream of the axis of the dam. The two gates and dam piers adjacent to the auxiliary lock were removed. The riverside wall of the new lock incorporated the right pier of the third gate. A 1,200-ft-long ported upper guard wall and a 1,200-ft-long solid lower guard wall were constructed. A 60-ft-wide tainter gate with a design similar to those of the existing dam was installed in the chamber of the auxiliary lock with the gate aligned with the existing gates.

The principal features of this plan were as follows (Figures 10 and 11 and Photos 26 and 27):

a. A 110- by 1,200-ft lock riverward of the auxiliary lock. The upper gate pintle of the new lock was located at sta 5+90A. This placed the gate pintle of the new lock 70 ft upstream of the axis of the dam.

b. A 1,200-ft-long ported guard wall with twenty-two 30-ft-diameter cells spaced 50 ft on centers and a 50-ft guard cell at the upper end of the wall. This provided twenty-two 20-ft-wide port openings and one 40-ft-wide port opening with the top of ports at el 448.5 (11 ft below normal pool of 459.5). The effective length of the guard wall measured from the upstream end of the center wall to the upstream end of the guard wall was 1,200 ft and would provide full protection for the design size tow.

c. A 1,200-ft-long solid lower guard wall extending downstream from the riverside lock wall.

d. Removal of the two dam piers and gates adjacent to the auxiliary lock to construct the new lock.

e. Construction of a 60-ft-wide tainter gate with the same design as the existing dam gates between the new lock and the existing 600-ft lock for passage of ice or flow during high riverflows.

f. Construction of two new 60-ft-wide tainter gates with the same design as the existing dam gates adjacent to the left end of the dam. The existing left abutment of the dam was removed along with the storage yard and reconstructed adjacent to the new gates.

Results

The model experiments were conducted using the same operating procedures for the dam and flow conditions as those used for Base Experiments. The new 60-ft-wide tainter gate between the locks was closed during all navigation riverflows. The new gate would be used to pass ice during periods when tows are not using either of the locks or used to pass flow with flood flows when the lock is closed to navigation.

Water-surface elevations. Water-surface elevations shown in Table 5 indicate that the slope of the water surface through the reach was generally the same as with Base Experiments. With open riverflows of 162,000 cfs and above, water-surface elevations at Gauge 4, in the upper lock approach, increased more than 1.0 ft. This can be attributed to the tendency for a head differential to build

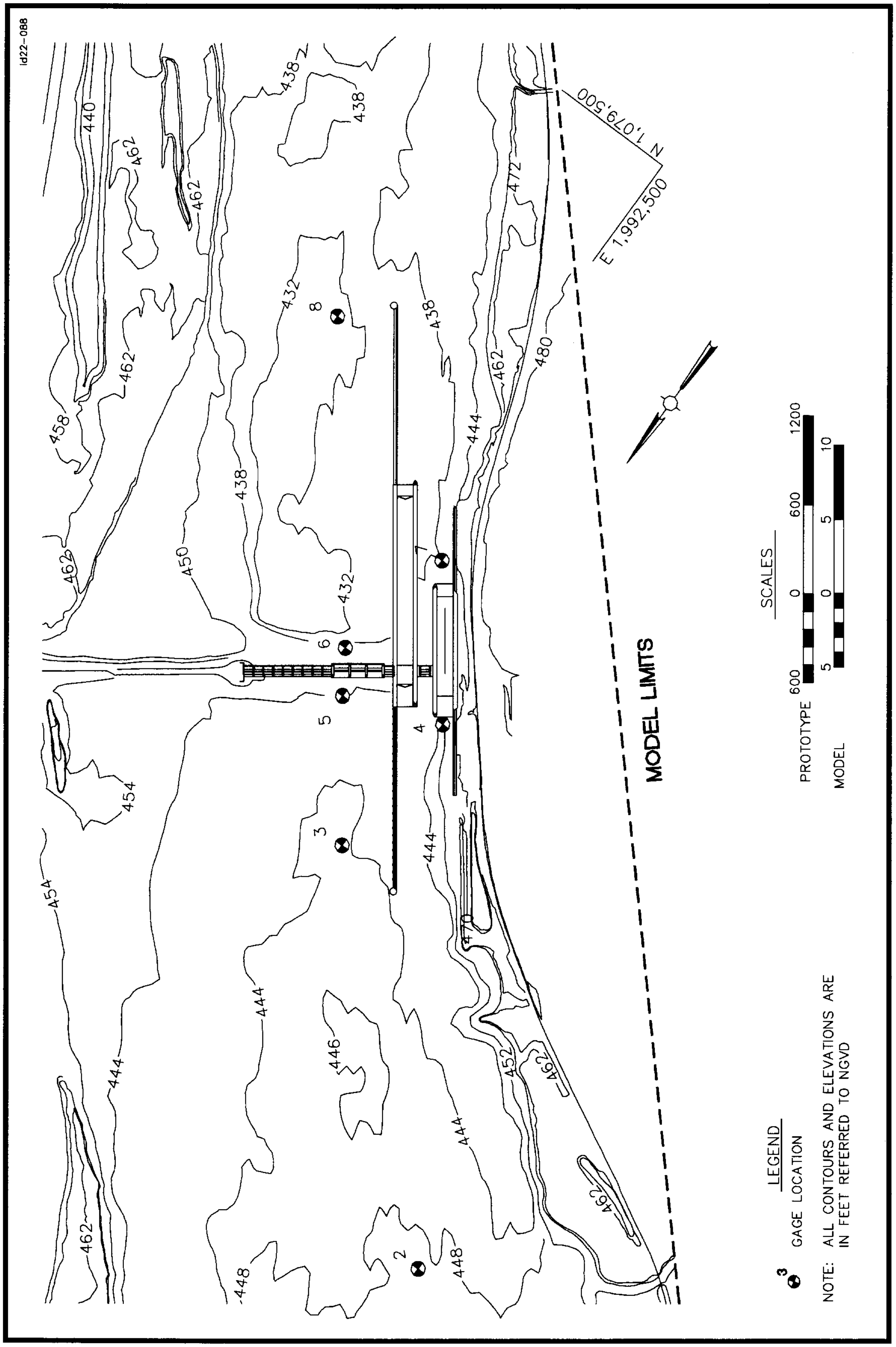


Figure 10. Lock Location 4, Plan A

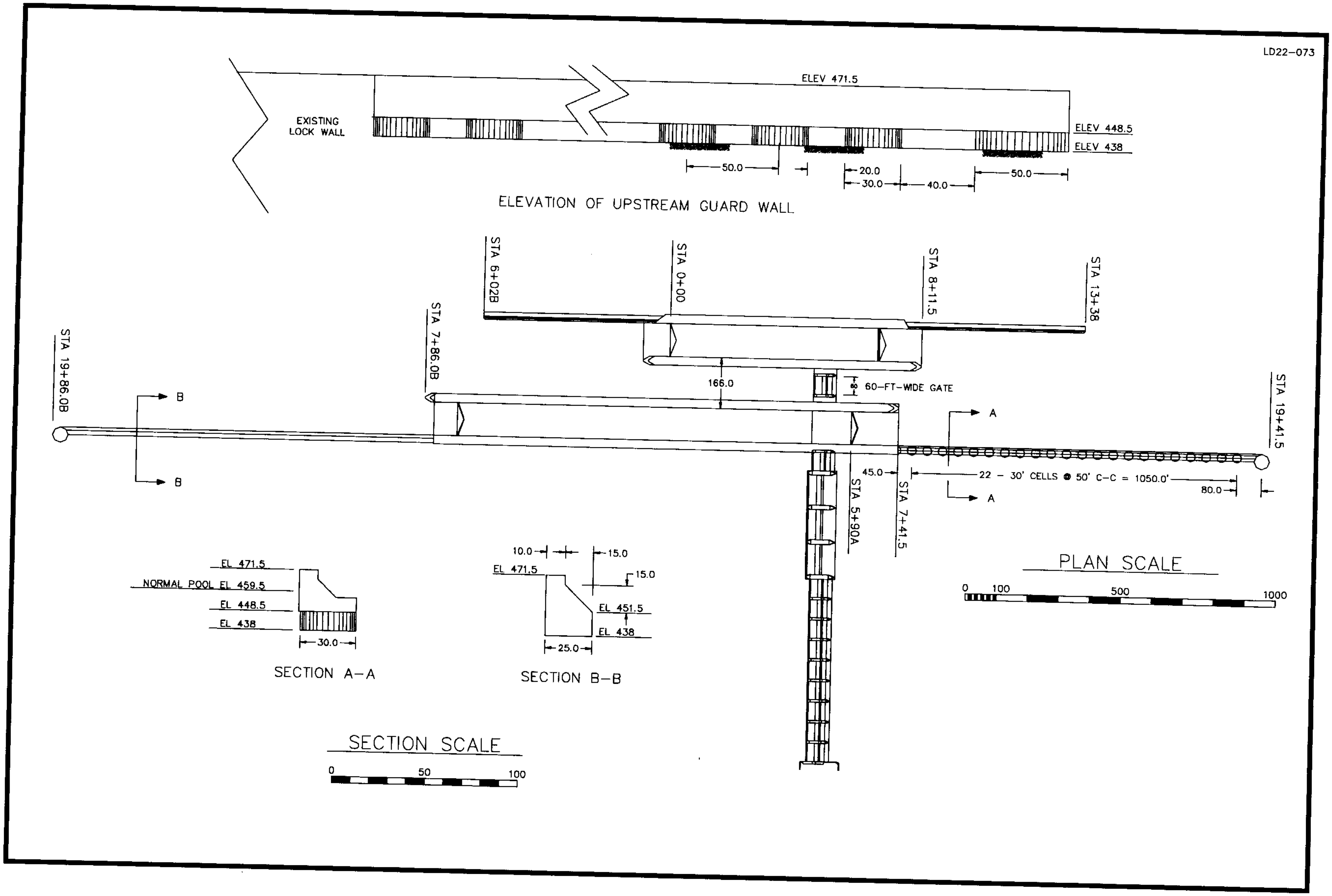


Figure 11. General plan and sections, Lock Location 4, Plan A

inside the riverside guard wall due to the amount of flow being intercepted by the guard wall. This tendency is also reflected in the water-surface elevations upstream of the lock with the 100,000-cfs controlled riverflow, which was controlled at Gauge 4. This resulted in the water-surface elevation upstream of Gauge 4 being 0.2 to 0.3 ft lower than those measured with Base Experiments. Water-surface elevations downstream of the dam increased slightly in the vicinity of the new 1,200-ft lock. The largest increase of 0.4 ft occurred at Gauge 6, which is immediately downstream of the dam.

Current directions and velocities. Currents upstream of the dam were generally the same as those of Base Experiments from the upstream end of the model to the upstream end of the right bank longitudinal dike where the new guard wall started influencing the currents. Current direction and velocity data shown in Plates 21-25 and dye pattern shown in Photo 28 indicate that the currents generally moved parallel to the right descending bank until reaching the upstream end of the longitudinal dike and then moved across the upper lock approach. The new ported guard wall intercepted most of the currents moving across the upper lock approach. Some currents were moving around the upstream end of the guard wall due to the alignment of the currents approaching the wall. The flow entering the upper lock approach was uniformly distributed along the wall and moved through the ports of the wall, except with the 276,000-cfs riverflow (Plate 25), where the flow was concentrated toward the upstream end of the wall and a large clockwise eddy formed in the approach. The currents downstream of the dam moved parallel to the lock wall from the dam to the downstream end of the lock, then turned toward the right bank, moving across the lock approach and around the downstream end of the lower guide wall. A large clockwise eddy formed along the right bank downstream of the lock and extended upstream into the lower approach of the existing 600-ft lock. The maximum velocity of the currents in the navigation channel upstream of the lock varied from about 1.8 to 4.4 fps about 8,000 ft upstream of the dam, 1.3 to 5.0 fps about 4,000 ft upstream of the dam where tows would start reducing speed to approach the lock, and about 1.7 to 5.0 fps near the upstream end of the new guard wall with the 50,000- and 220,000-cfs riverflows, respectively. A maximum current velocity of 6.5 fps occurred near the upstream end of the guard wall with the 276,000-cfs riverflow. The maximum velocity of the currents in the navigation channel downstream of the lock varied from about 3.7 to 7.9 fps near the downstream end of the lower guard wall and from about 3.5 to 8.4 fps about 3,000 ft downstream of the lock for riverflows of 50,000 and 276,000 cfs, respectively.

Navigation conditions. Navigation conditions were improved for tows entering and leaving the upper lock approach with all riverflows evaluated compared with those of Base Experiments. With the 50,000-cfs riverflow, downbound tows could drive toward the upper lock approach, align with the guard wall about four tow lengths upstream of the wall, start reducing speed about two tow lengths upstream of the wall, and enter the lock approach at a slow speed (Photo 29). As the tow approached the upper end of the right bank longitudinal dike, the flow moving from the right bank toward the dam started moving the tow toward the dam. However, the velocity of the currents was low and the tow was able to control its alignment with a minimum of maneuvering and enter the approach without any difficulties. As the flow increased to 162,000 cfs, a downbound tow was required to drive close along the right bank, start flanking about three tow lengths upstream of the upper end of the guard wall, reduce speed while moving the stern of the tow into the right bank, ease the tow down the right bank, and swing the head of the tow landward of the guard wall (Photo 30). This maneuver was very difficult, and any error in judgment or alignment could result in the tow striking the upper end of the guard wall. Upbound tows could move away from the guard wall, take a set toward the right bank to counteract the currents moving toward the dam from the right bank, and exit the approach without any major difficulties (Photo 31).

Tows could enter and leave the lower lock approach without any major difficulties with all riverflows evaluated. Downbound tows could move away from the lower guard wall, turn riverward as they cleared the downstream end of the wall, and move toward midchannel (Photo 32). Upbound tows could approach the lock from midchannel to a point about two tow lengths downstream of the lower end of the guard wall, start moving toward the right bank and taking a set toward the left bank to counteract the current moving around the lower end of the guard wall, and enter the lock approach without any major difficulties (Photo 33). As the tow entered the protection of the guard wall, the clockwise eddy that formed along the right bank downstream of the approach necessitated maneuvering by the tow. The tow started maneuvering to approach the guard wall by flanking to reduce speed and to counteract the rotation of the eddy. With the higher riverflows and faster eddy velocities, considerable maneuvering can be required for the tow to align with the wall and push into the lock chamber.

Recommendations for future experiments

If this location is selected as the recommended location, additional experiments should be conducted to improve navigation conditions at the site. Some of the recommended experiments are as follows:

a. A system of dikes similar to that of Plan B should be developed to improve navigation conditions for tows entering and leaving the upper lock approach. The lengths of the dikes may be slightly different from those developed in Plan B.

b. A 50- to 75-ft-long wing wall angled 10 to 15 degrees off the lower riverside lock wall could aid a tow approaching the lock chamber by guiding the head of the tow into the guard wall.

c. Realignment of the right descending bank immediately downstream of the lock may reduce the size and intensity of the eddy that forms between the new guard wall and the right bank. This could reduce the maneuvering required for a tow to approach the lock and align with the guard wall.

d. Moving the riverside 1,200-ft-long solid lower guard wall to the landside lower lock wall may improve navigation conditions for tows entering and leaving the new 1,200-ft lock. However, a landside guide wall could restrict the use of the existing 600-ft-long lock.

Approach Time Experiments

The approach times for downbound tows were recorded both for existing conditions and all lock locations using a video tracking system. The time reported in Table 6 is the time required for a tow to navigate the reach from a point 6,720 ft upstream of the axis of the dam to a point where the tow was aligned to enter the lock chamber. The time reported for existing conditions is a combination of field data and model data. The field of view of the field camera did not provide a good view or means for measuring the location of the tow at the extreme upstream location. Therefore, model data were used to measure the time required for a tow to move from a point 6,720 ft upstream of the axis of the dam to the upstream end of the right bank stone dike, which is about 1,800 ft upstream of the axis of the dam. The field data provide better measurements of the time required for a tow to move from the upstream end of the dike into the lock chamber due to the maneuvering required and the need for a helper towboat. The two times were then combined to provide an overall time for a tow to approach the lock. The model tow was operated at about 2 mph above the speed of the currents to maintain steerage except when the tow was entering the lock approach. As the tow approached the lock, it reduced speed to enter the lock approach at a slower speed.

All of the evaluated lock locations improved (reduced) the transit time except with riverflows greater than 50,000 cfs and Lock Location 2, Plan A, when tows could not enter the upper lock approach due the extreme crosscurrents. Most of the improvement in the transit times can be attributed to the new lock at all locations having a ported upper guard wall and in the case of Lock Location 2, Plan B, an improved channel alignment approaching the lock. Lock Location 2, Plan B, showed the most improved transit time. This can be attributed to downbound tows entering the lock approach without maneuvering to reduce speed or align with the guard wall. With Locations 3 and 4, the tow was required to reduce speed and maneuver to align with the guard wall due to currents moving across the upper lock approach. It should be noted that using the approach times as the only criterion for selection of a location is not advisable.

4 Discussion of Results and Conclusions

Limitations of Model Results

Analysis of the results of this investigation is based on a study of the effects of various plans and modifications on water-surface elevations and current directions and velocities and the effects of the resulting currents on the behavior of the model towboat and tow. In evaluating experiment results, it should be considered that small changes in current directions and velocities are not necessarily changes produced by a modification in the plan since several floats introduced at the same point may follow a different path and move at somewhat different velocities because of pulsating currents and eddies. Current directions and velocities shown in the plates were obtained with floats submerged to a depth of a loaded barge (9-ft prototype) and are indicative of the currents that would affect the behavior of tows.

The small scale of the model made it difficult to reproduce accurately the hydraulic characteristics of the prototype structures or to measure water-surface elevation within an accuracy greater than about ±0.1 ft prototype. Also, current directions and velocities were based on steady flows and would be somewhat different with varying flows. The model was of the fixed-bed type and was not designed to reproduce overall sediment movement that might occur in the prototype with the various plans; therefore, changes in channel configuration resulting from scouring and deposition and any resulting changes in current directions and velocities were not evaluated.

Recommendations for improving navigation conditions with the various plans are presented for planning purposes and should not be used for final design of the project without additional model experiments to verify navigation conditions with the proposed modification.

Summary of Results and Conclusions

The following results and conclusions were developed during the investigation:

a. With all locations evaluated, a system of dikes upstream of the lock along the right descending bank would improve navigation conditions for tows entering and leaving the locks.

b. A design that features a ported upper guard wall would eliminate the need for a helper towboat, provided a system of dikes is provided along the right descending bank to control the current approaching the lock. The effective length of the guard wall should be long enough to provide protection for the full length of the design tow.

c. Model data indicate satisfactory navigation conditions can be established for tows entering and leaving the new lock with all lock locations evaluated. However, Lock Locations 3 and 4 would require less modification to the existing bank line to provide acceptable navigation conditions.

d. Lock Location 2 required a system of dikes upstream of the lock along the right descending bank, like those shown in Figure 7, to establish satisfactory navigation conditions for downbound tows approaching the lock.

e. Lock Location 3 provided marginally acceptable navigation conditions for tows entering and leaving the new lock without a system of dikes upstream of the lock along the right descending bank. However, a system of dikes similar to those shown in Lock Location 2, Plan B, would improve navigation conditions for tows entering and leaving the lock.

f. Lock Location 4 provided acceptable navigation conditions for tows entering and leaving the new lock without any modification to the existing bank or a system of dikes upstream of the lock along the right descending bank. However, a system of dikes similar to those of Lock Location 2, Plan B, would improve navigation conditions for tows entering and leaving the lock. The 60-ft-wide tainter gate between the locks should be closed during all navigation riverflows.

g. With Lock Location 4, moving the riverside 1,200-ft-long solid lower guard wall to the landside lower lock wall may improve navigation conditions for tows entering and leaving the new 1,200-ft lock. However, a landside guide wall could restrict the use of the existing 600-ft-long lock.

Table 1
Water-Surface Elevations, Base Experiment

Gauge No.	Water-Surface Elevations, ft NGVD, for Discharge, cfs				
	50,000	100,000	162,000	220,000	276,000
1	459.6	459.9	460.7	464.3	467.4
2	459.6	459.7	460.1	463.9	467.1
3	459.5	459.5	459.6	463.5	466.7
4	459.5[1]	459.5[1]	459.5[1]	463.5	466.7
5	459.5	459.4	459.4	463.4	466.5
6	451.3	454.7	458.9	462.9	466.1
7	451.3[1]	454.7[1]	458.8	462.8[1]	466.1[1]
8	451.2	454.6	458.7	462.8	466.1
9	451.0	454.4	458.6	462.6	465.8

[1] Controlled elevation.

Table 2
Water-Surface Elevations, Lock Location 2, Plan A

Gauge No.	Water-Surface Elevations, ft NGVD, for Discharge, cfs				
	50,000	100,000	162,000	220,000	276,000
1	459.5	459.8	460.7	464.3	467.4
2	459.5	459.6	460.1	463.9	467.1
3	459.4	459.4	459.6	463.5	466.7
4	459.5[1]	459.5*	459.9	463.7	467.0
5	459.4	459.4	459.4	463.4	466.5
6	451.4	454.8	459.0	463.0	466.1
7	451.3	454.7	458.8	462.8	466.2
8	451.2	454.6	458.7	462.8	466.1
9[1]	451.0	454.4	458.6	462.6	465.8

[1] Controlled elevation.

Table 3
Water-Surface Elevations, Lock Location 2, Plan B

Gauge No.	Water-Surface Elevations, ft NGVD, for Discharge, cfs				
	50,000	100,000	162,000	220,000	276,000
1	459.9	460.1	461.0	464.5	467.5
2	459.8	459.9	460.4	464.1	467.2
3	459.6	459.6	459.8	463.7	466.8
4	459.5[1]	459.5[1]	460.0	463.9	467.1
5	459.7	459.4	459.4	463.5	466.7
6	451.1	454.8	458.9	463.0	466.3
7	451.1	454.7	458.8	462.9	466.2
8	451.2	454.6	458.7	462.8	466.1
9[1]	451.0	454.4	458.6	462.6	465.8

[1] Controlled elevation.

Table 4
Water-Surface Elevations, Lock Location 3, Plan A

Gauge No.	Water-Surface Elevations, ft NGVD, for Discharge, cfs				
	50,000	100,000	162,000	220,000	276,000
1	459.6	459.8	460.7	464.3	467.4
2	459.6	459.5	460.1	463.9	467.1
3	459.5	459.3	459.6	463.5	466.7
4	459.5[1]	459.5[1]	459.7	463.7	466.9
5	459.6	459.2	459.5	463.4	466.5
6	451.3	454.8	459.2	463.0	466.2
7	451.2	454.6	458.9	462.8	466.1
8	451.2	454.6	458.9	462.8	466.1
9[1]	451.0	454.4	458.6	462.6	465.8

[1] Controlled elevation.

Table 5
Water-Surface Elevations, Lock Location 4, Plan A

Gauge No.	Water-Surface Elevations, ft NGVD, for Discharge, cfs				
	50,000	100,000	162,000	220,000	276,000
1	459.7	459.6	461.2	464.8	467.8
2	459.6	459.4	460.6	464.4	467.5
3	459.5	459.3	460.1	464.0	467.1
4	459.5[1]	459.5[1]	460.7	464.4	467.5
5	459.5	459.2	459.9	463.7	466.9
6	451.7	454.8	458.9	463.3	466.5
7	451.3	454.5	458.7	462.7	465.9
8	451.4	454.6	458.9	463.0	466.3
9[1]	451.0	454.4	458.6	462.6	465.8

[1] Controlled elevation

Table 6
Downbound Tow Approach Times[1]

Lock Location	Discharge, cfs	Approach Time, min[1]
Existing Condition[2]	50,000	22.26 + 19.40 = 41.66
	162,000	19.25 + 22.88 = 42.13
	276,000	22.40 + 14.09 = 36.49
2, Plan A	50,000	25,04
	162,000	--[3]
	276,000	--[3]
2, Plan B	50,000	26.89
	162,000	21.01
	276,000	18.65
3	50,000	32.38
	162,000	46.58
	276,000	45.57
4	50,000	28.43
	162,000	36.08
	276,000	29.43

[1] Approach times are measured from sta 67+20 to lock chamber.
[2] Existing conditions measurements are a combination of field data and model data. Model data were used from sta 67+20 to upstream end of right bank longitudinal dike, and field data were used to time maneuvering required for tow to enter lock chamber (including time required for helper tow). Approach times were calculated using the following formula: model data + field data = total approach time.
[3] Tow unable to enter upper lock approach

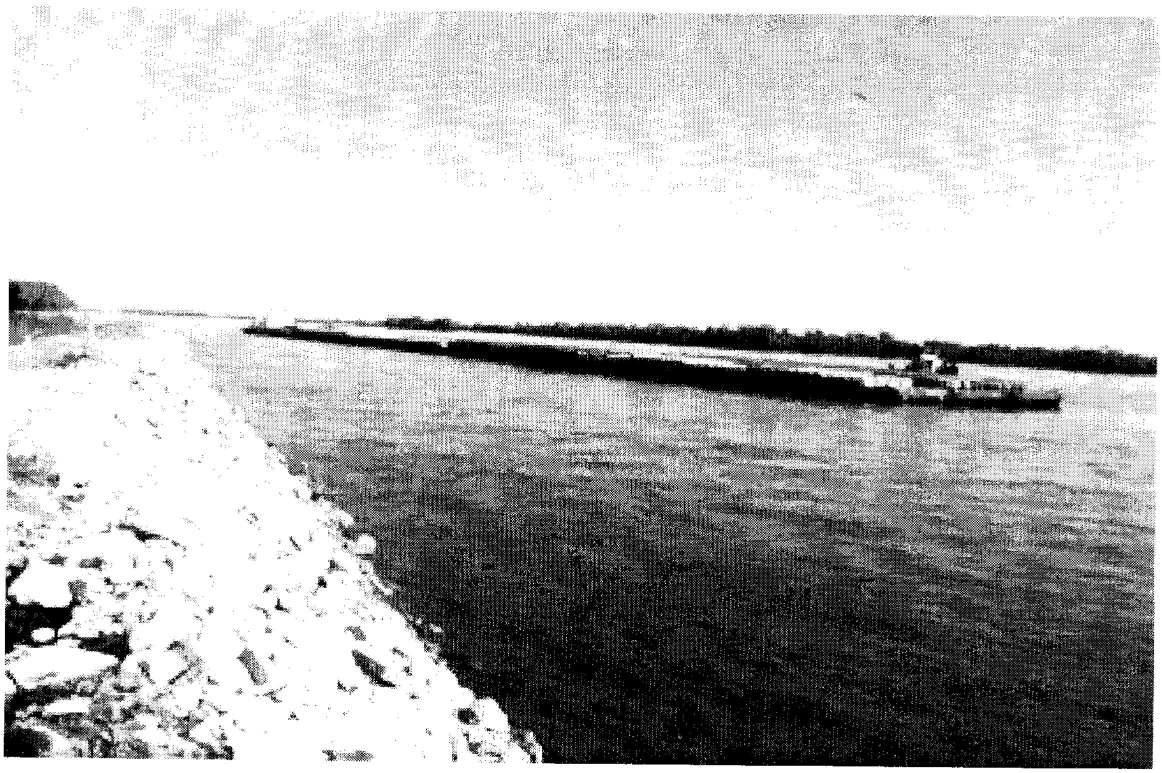


Photo 1. Looking upstream, showing towboat flanking stern of tow close to rock dike

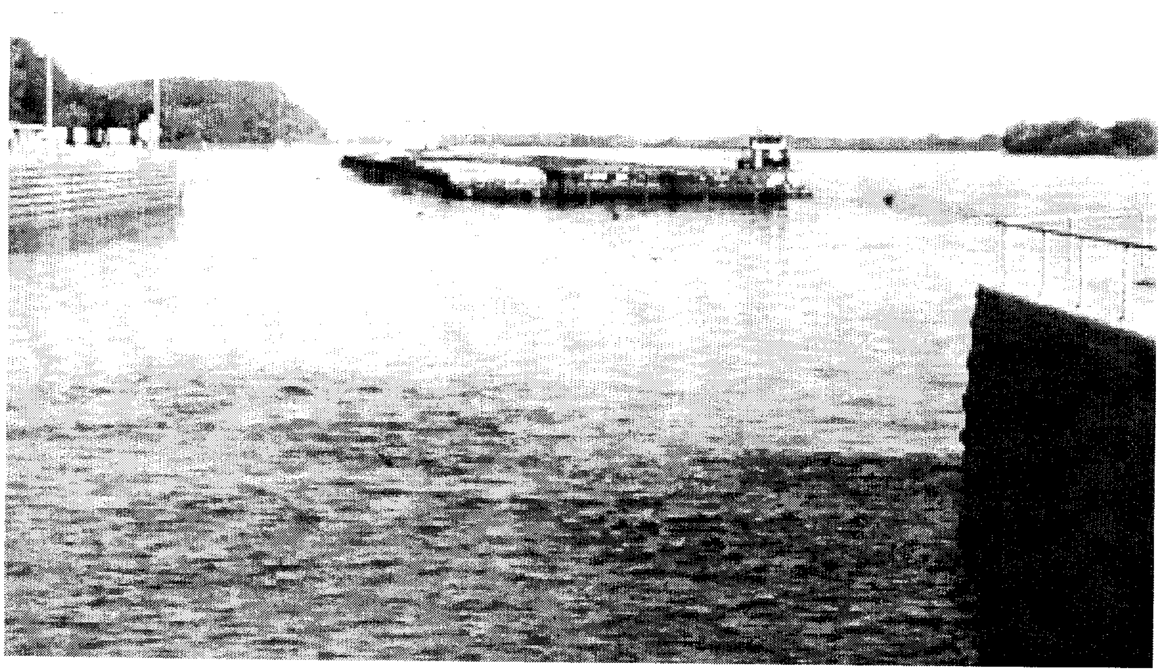


Photo 2. Looking upstream, showing helper towboat pushing the head of a downbound tow into the guide wall. Note clearance between stern of tow and rock dike.

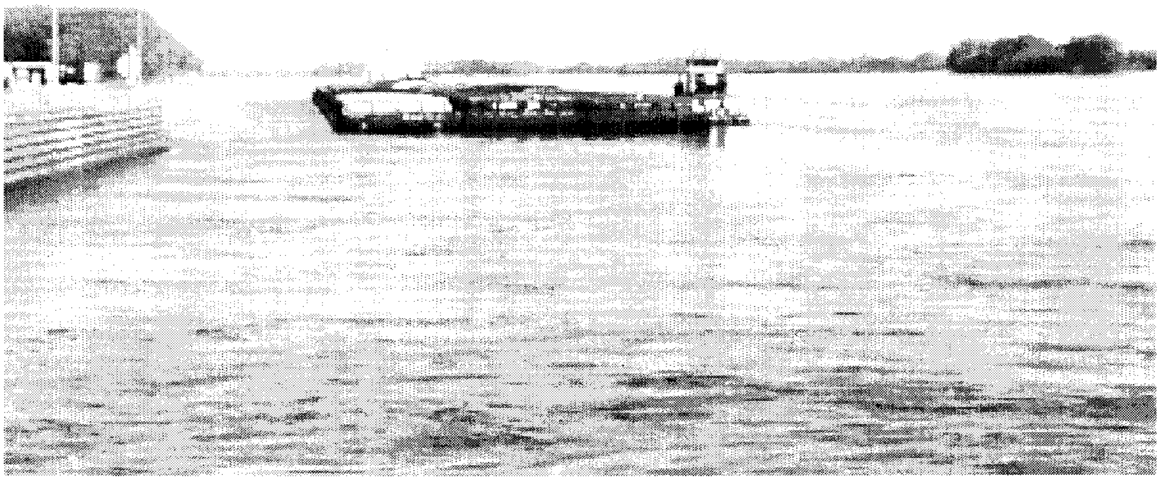


Photo 3. Looking upstream, showing helper towboat pushing the head of a downbound tow into the guide wall

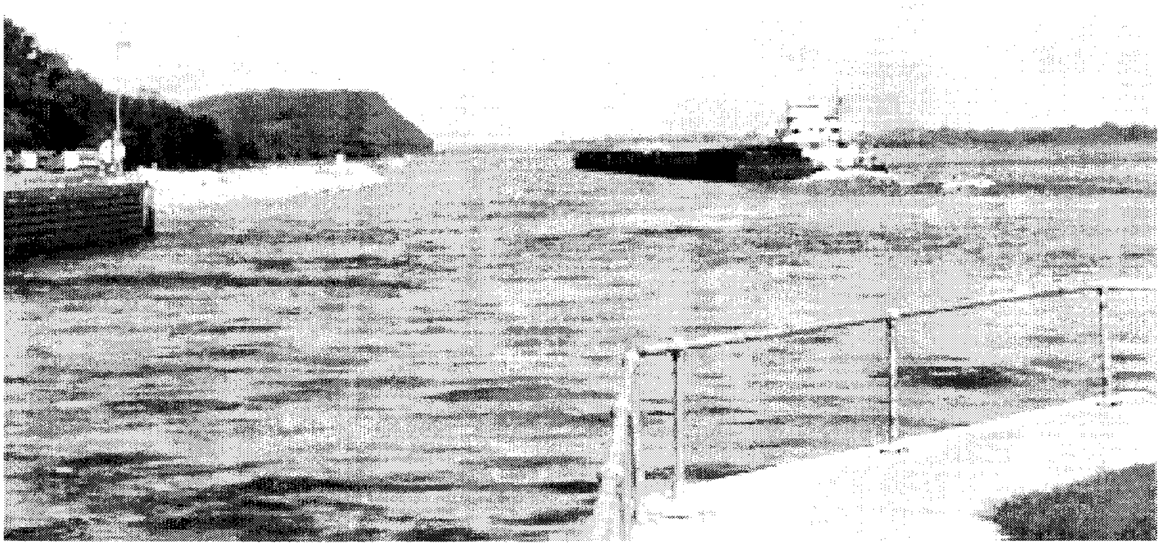


Photo 4. Looking upstream, showing upbound tow leaving lock. Note landward set of tow necessary to counteract currents moving across upper lock approach

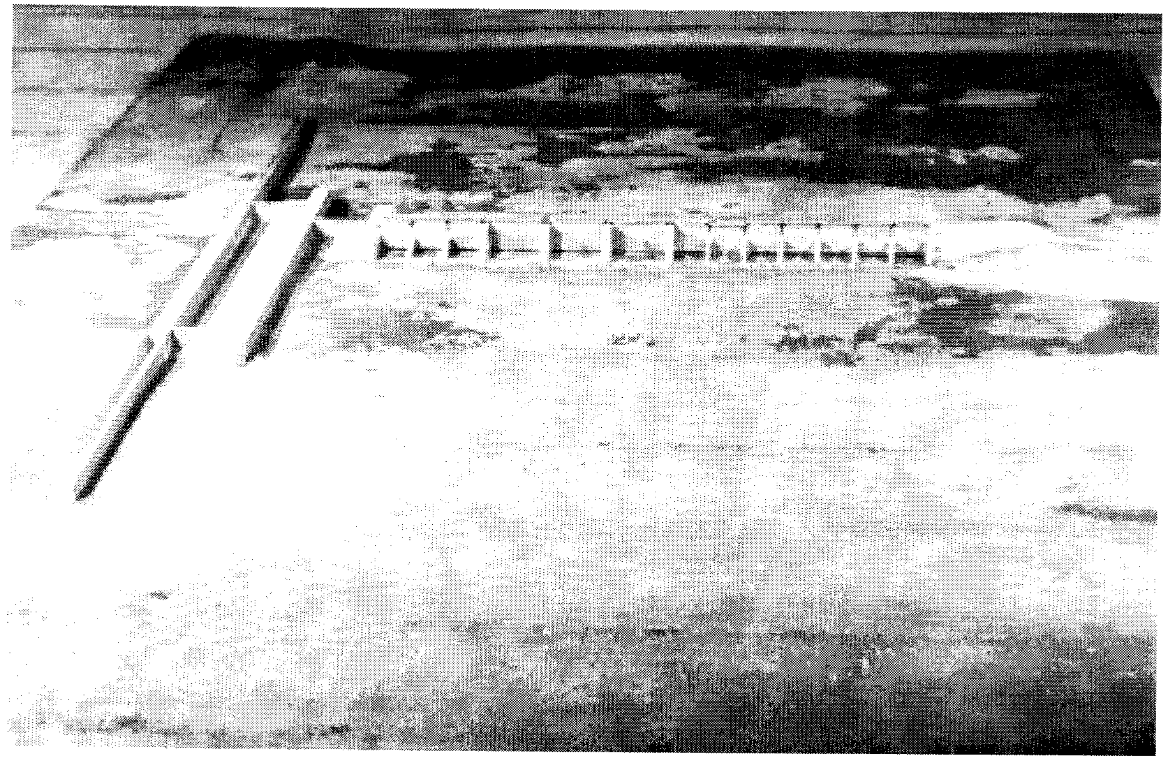


Photo 5. Existing structures, looking upstream

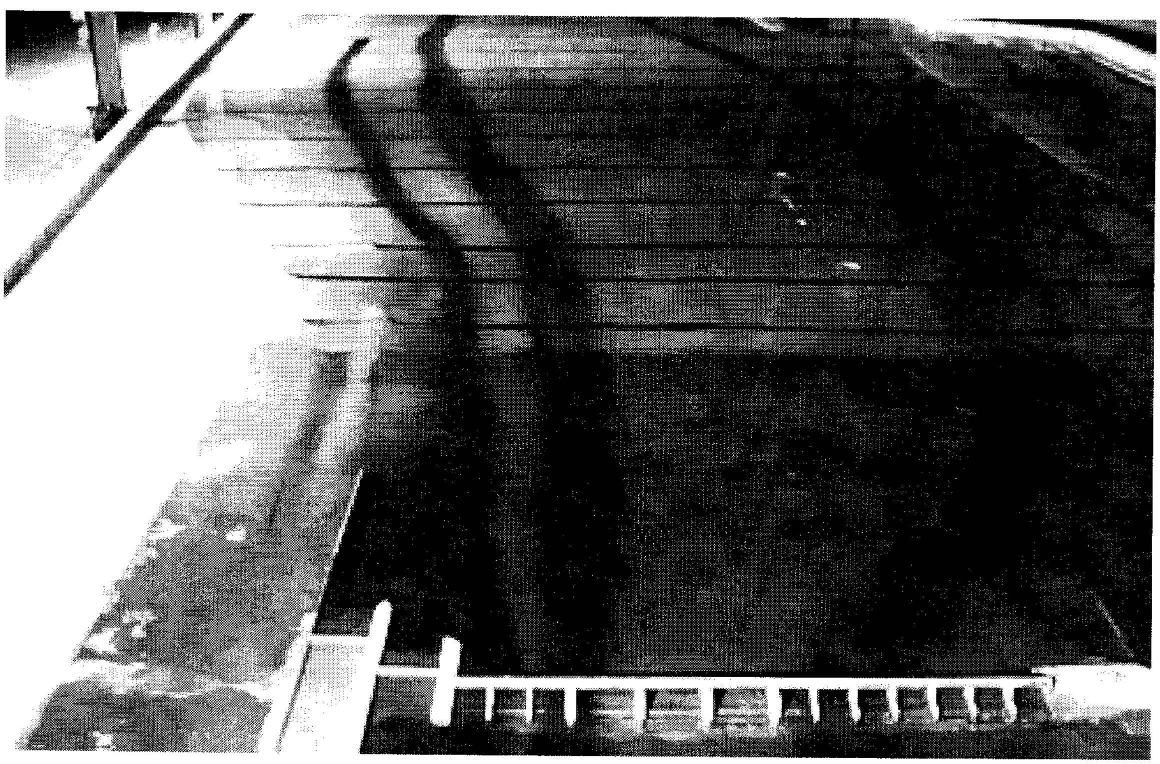


Photo 6. Existing conditions, looking upstream, discharge 162,000 cfs, dye showing current pattern approaching lock

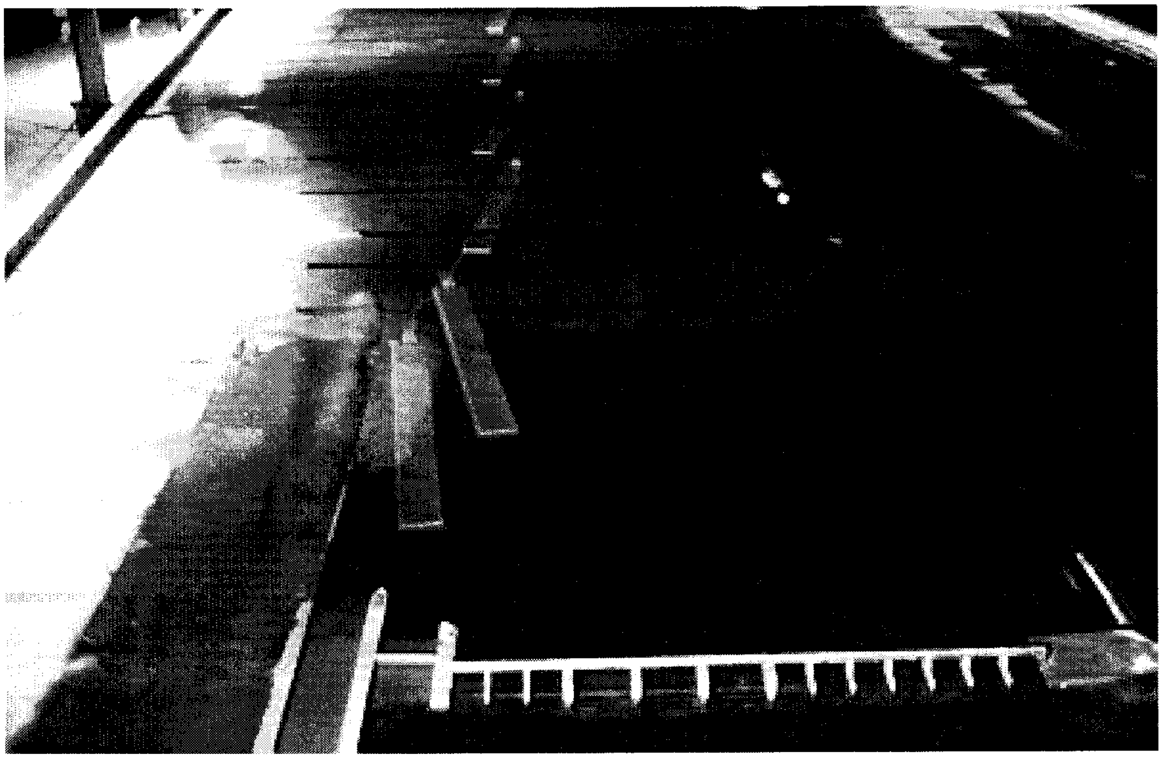


Photo 7. Existing conditions, looking upstream, discharge 162,000 cfs, path of downbound tow approaching 600-ft lock

Photo 8. Existing conditions, looking upstream, discharge 162,000 cfs, path of upbound tow leaving 600-ft lock

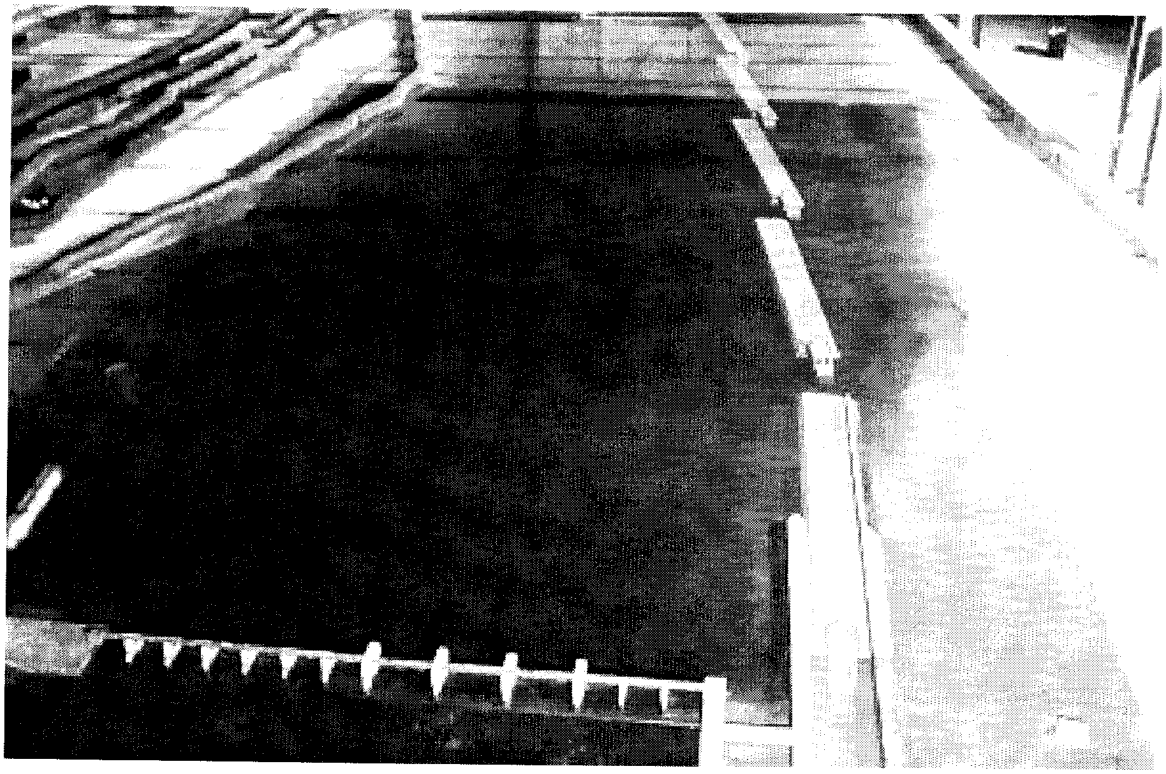


Photo 9. Existing conditions, looking downstream, discharge 162,000 cfs, path of downbound tow leaving 600-ft lock

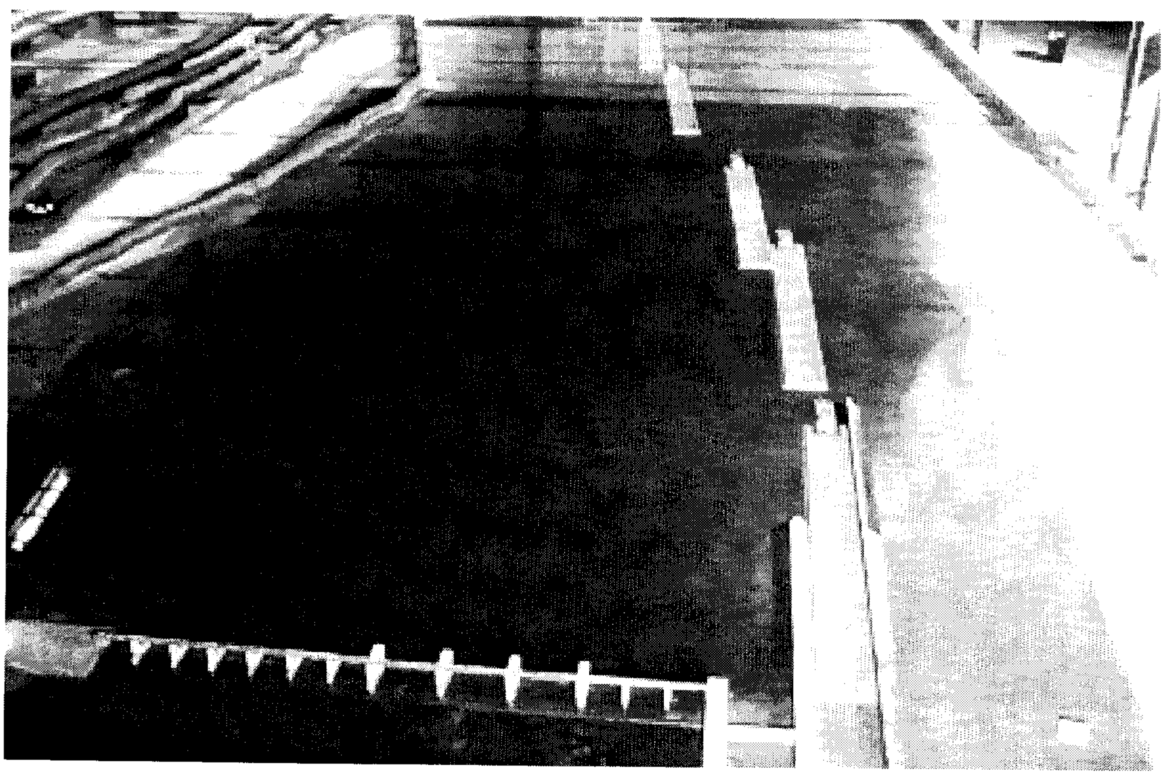


Photo 10. Existing conditions, looking downstream, discharge 162,000 cfs, path of upbound tow approaching 600-ft lock

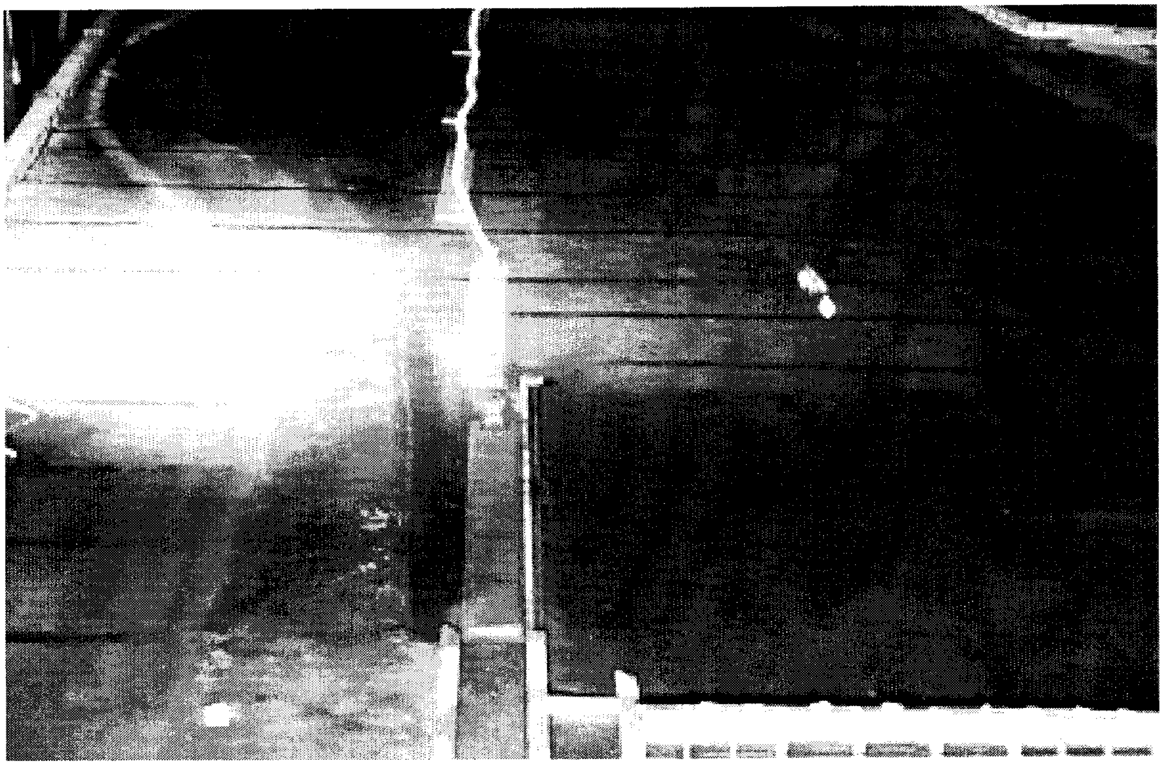


Photo 11. Lock Location 2, Plan A, looking upstream, discharge 50,000 cfs, showing path of downbound tow approaching 1,200-ft lock

Photo 12. Lock Location 2, Plan A, looking upstream, discharge 162,000 cfs, showing path of downbound tow approaching 1,200-ft lock

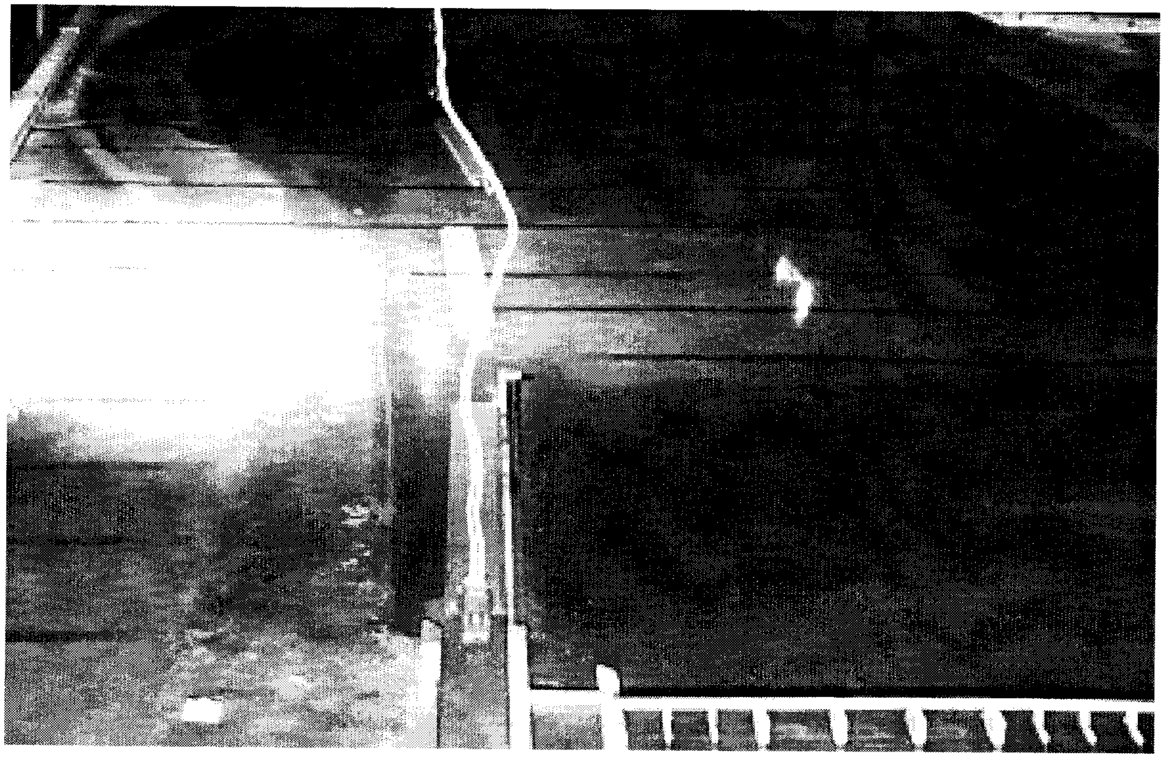


Photo 13. Lock Location 2. Plan A. looking upstream, discharge 162,000 cfs, showing path of upbound tow leaving 1,200-ft lock

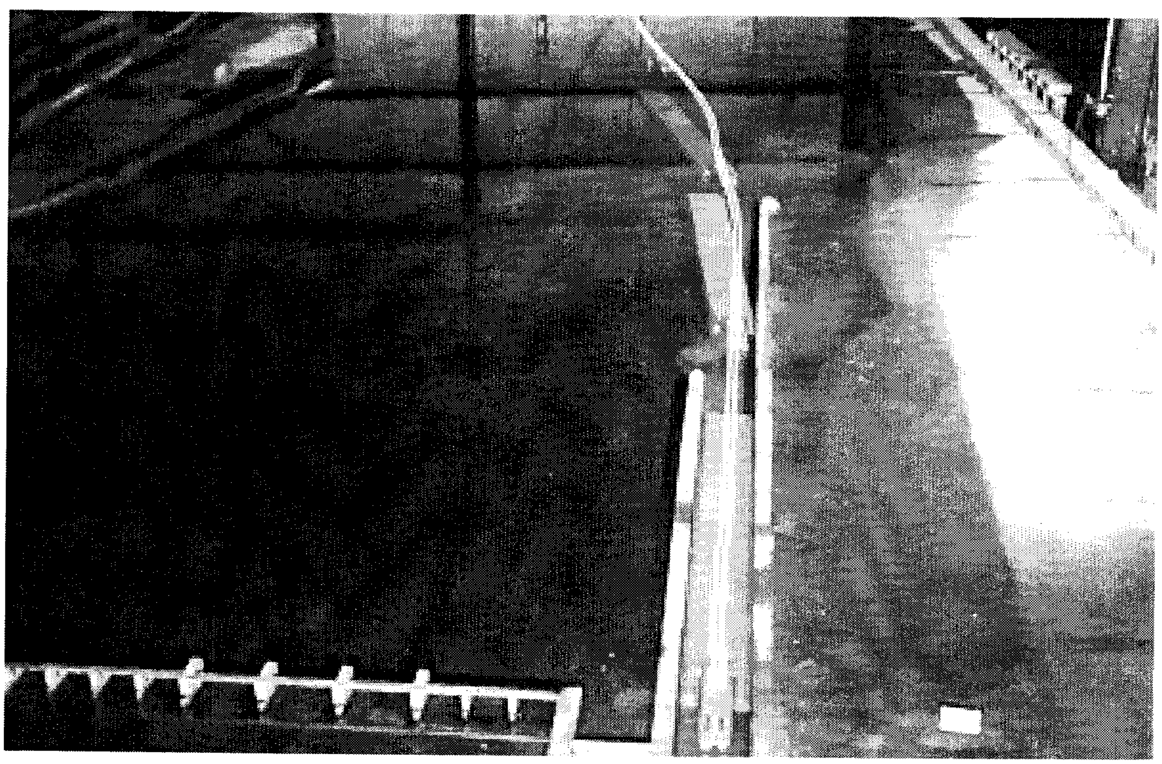


Photo 14. Lock Location 2. Plan A. looking downstream, discharge 162,000 cfs, showing path of downbound tow leaving 1,200-ft lock

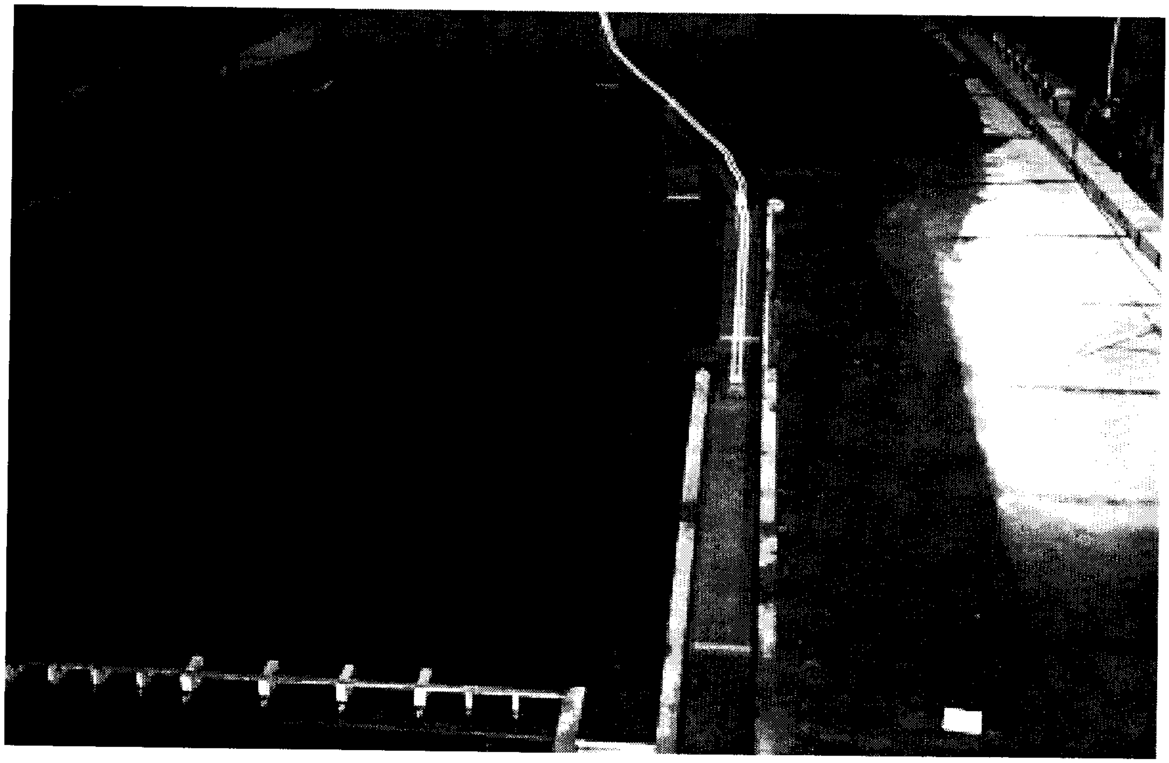


Photo 15. Lock Location 2, Plan A, looking downstream, discharge 162,000 cfs, showing path of upbound tow approaching 1,200-ft lock

Photo 16. Lock Location 2, Plan B, looking upstream, showing upper approach of 1,200-ft lock

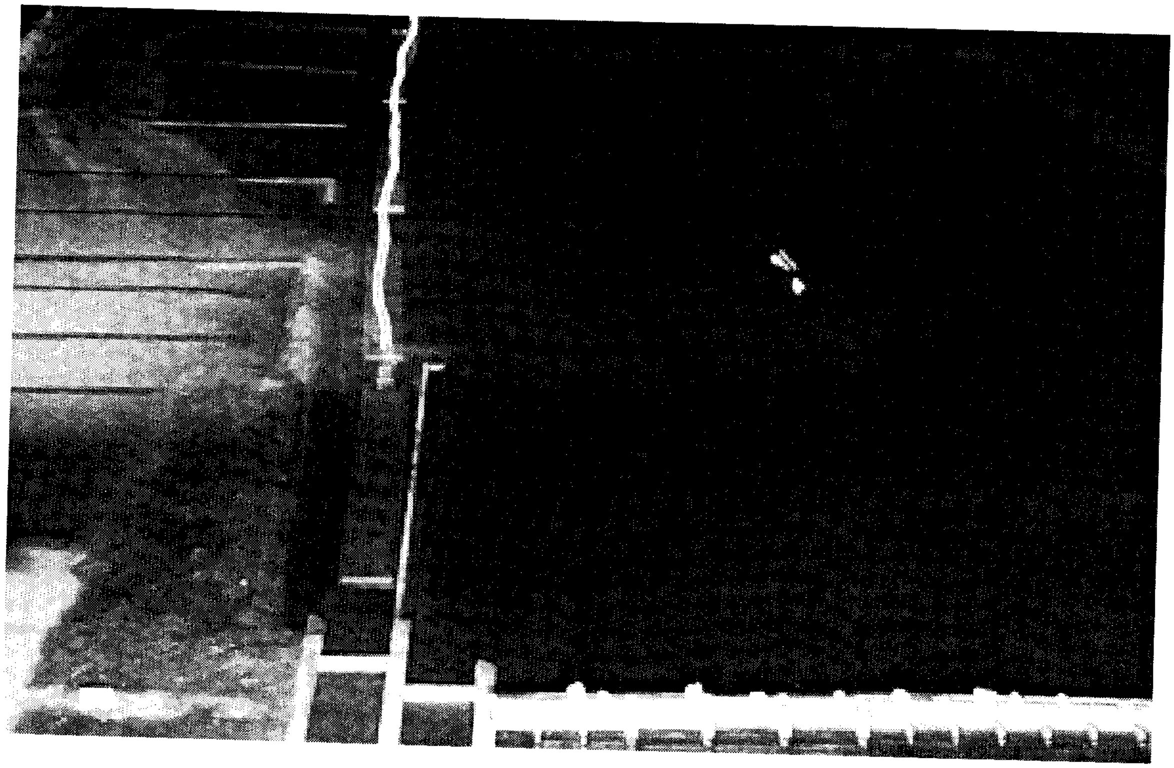


Photo 17. Lock Location 2. Plan B, looking upstream, discharge 50,000 cfs, showing path of downbound tow approaching 1,200-ft lock

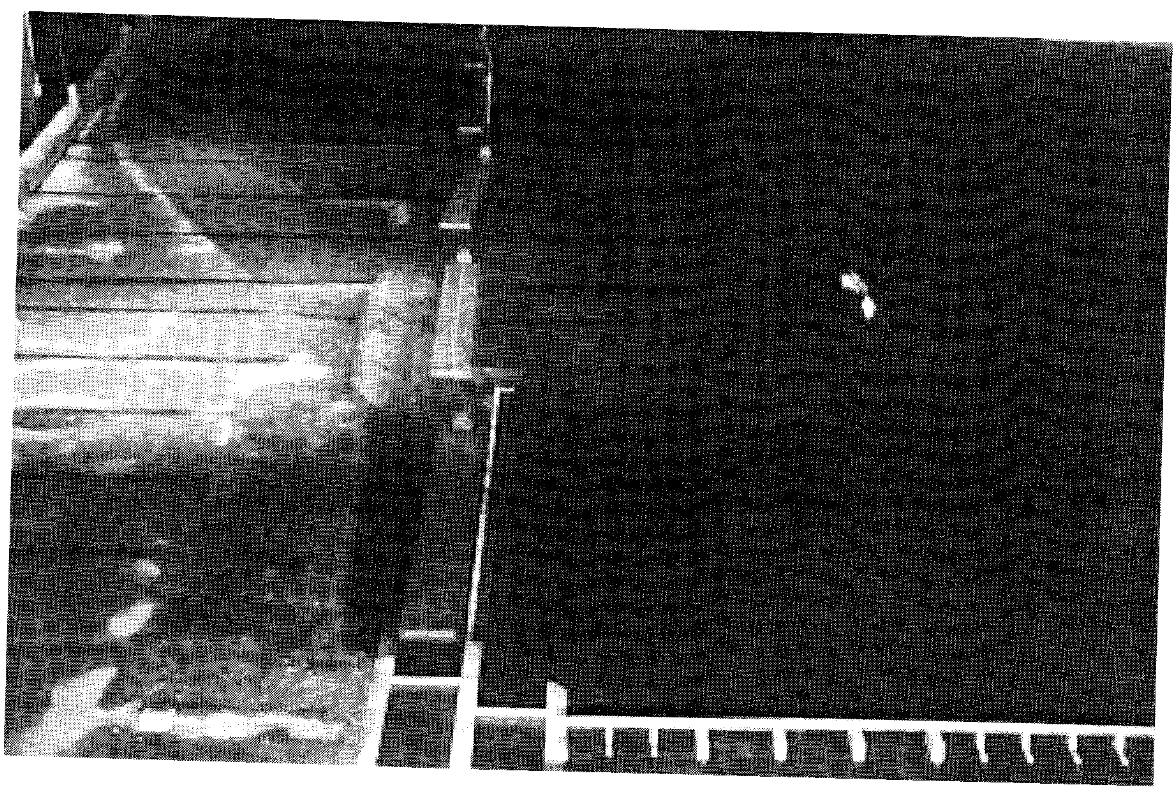


Photo 18. Lock Location 2, Plan B, looking upstream, discharge 162,000 cfs, showing path of downbound tow approaching 1,200-ft lock

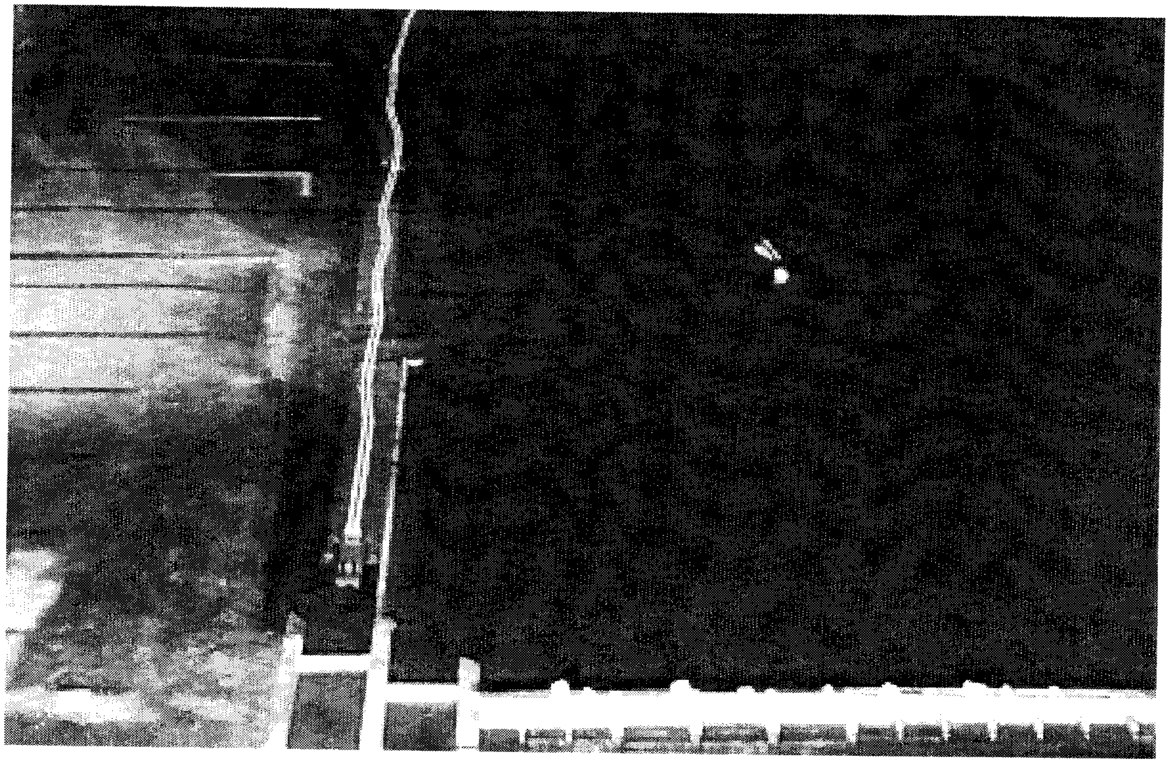


Photo 19. Lock Location 2. Plan B, looking upstream, discharge 162,000 cfs, showing path of upbound tow leaving 1,200-ft lock

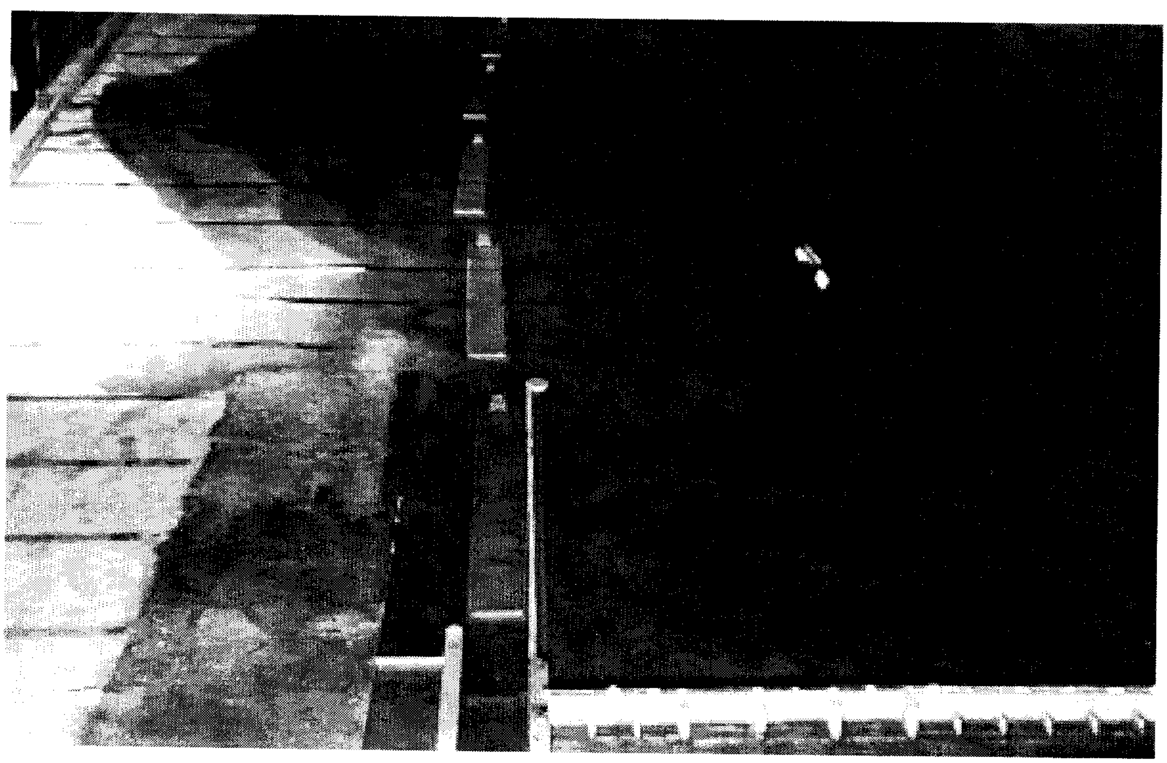


Photo 20. Lock Location 3. Plan A, looking upstream, discharge 50,000 cfs, showing path of downbound tow approaching 1,200-ft lock

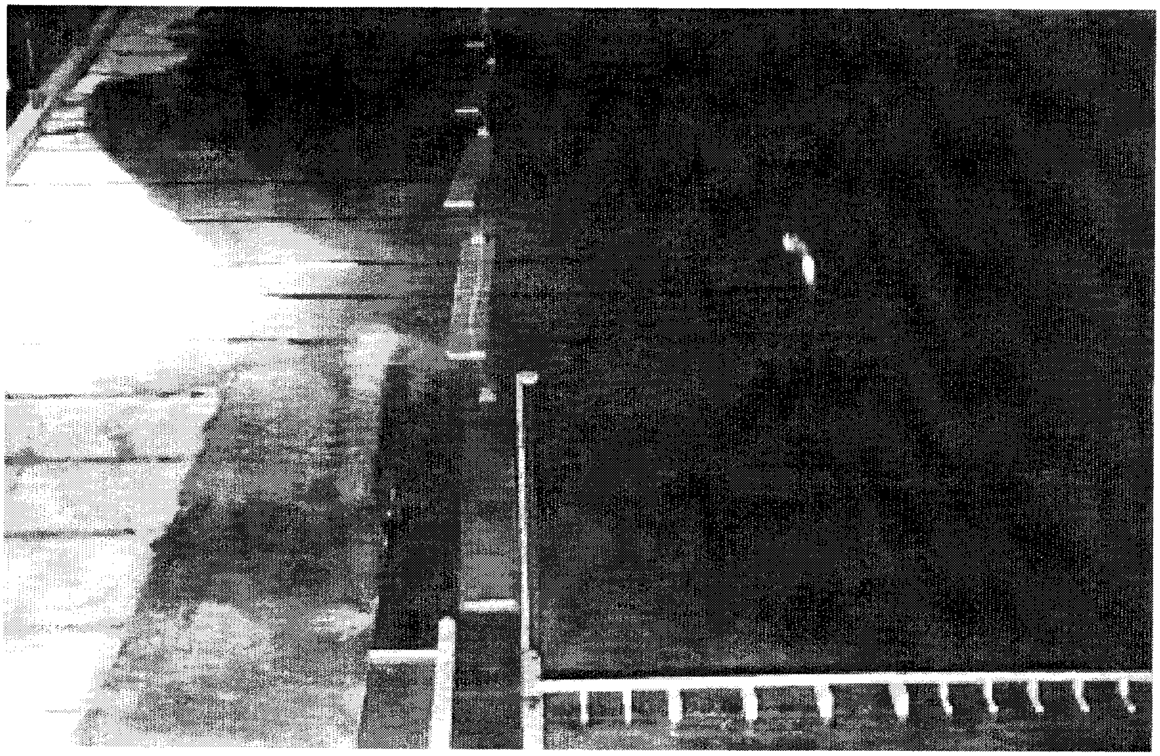


Photo 21. Lock Location 3. Plan A. looking upstream, discharge 162,000 cfs, showing path of downbound tow approaching 1,200-ft lock

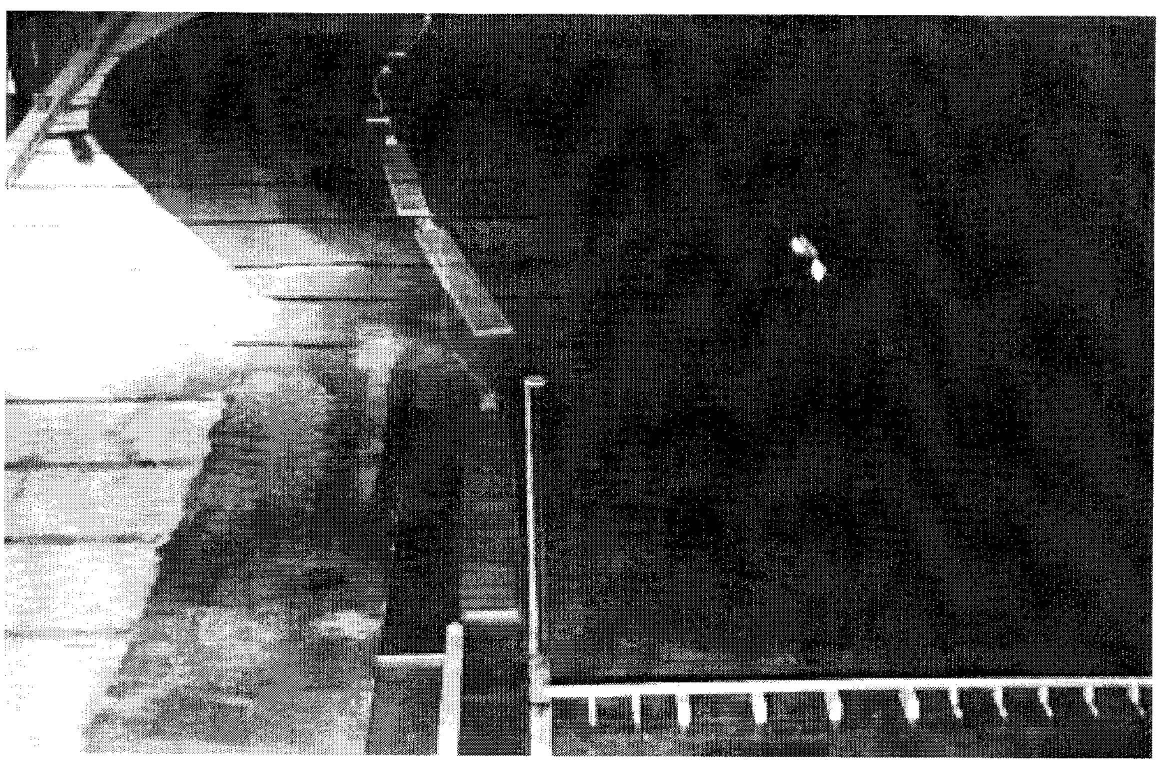


Photo 22. Lock Location 3. Plan A. looking upstream, discharge 276,000 cfs, showing path of downbound tow approaching 1,200-ft lock

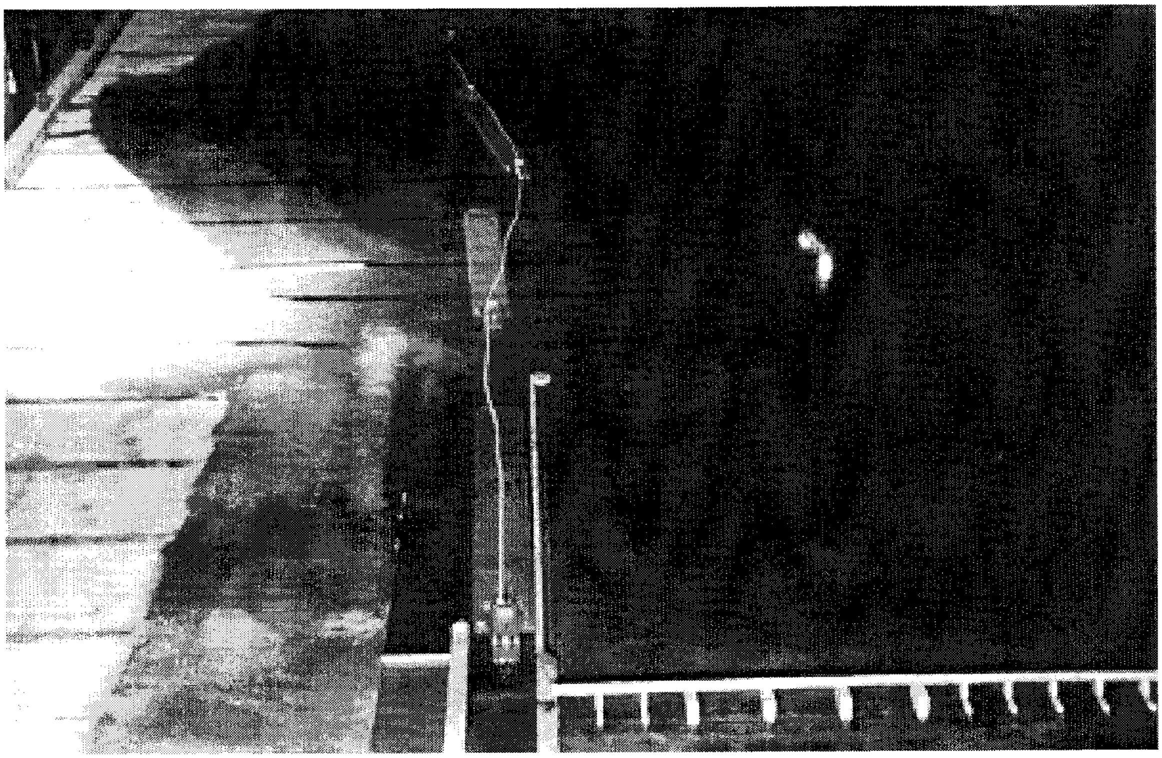


Photo 23. Lock Location 3, Plan A, looking upstream, discharge 162,000 cfs, showing path of upbound tow leaving 1,200-ft lock

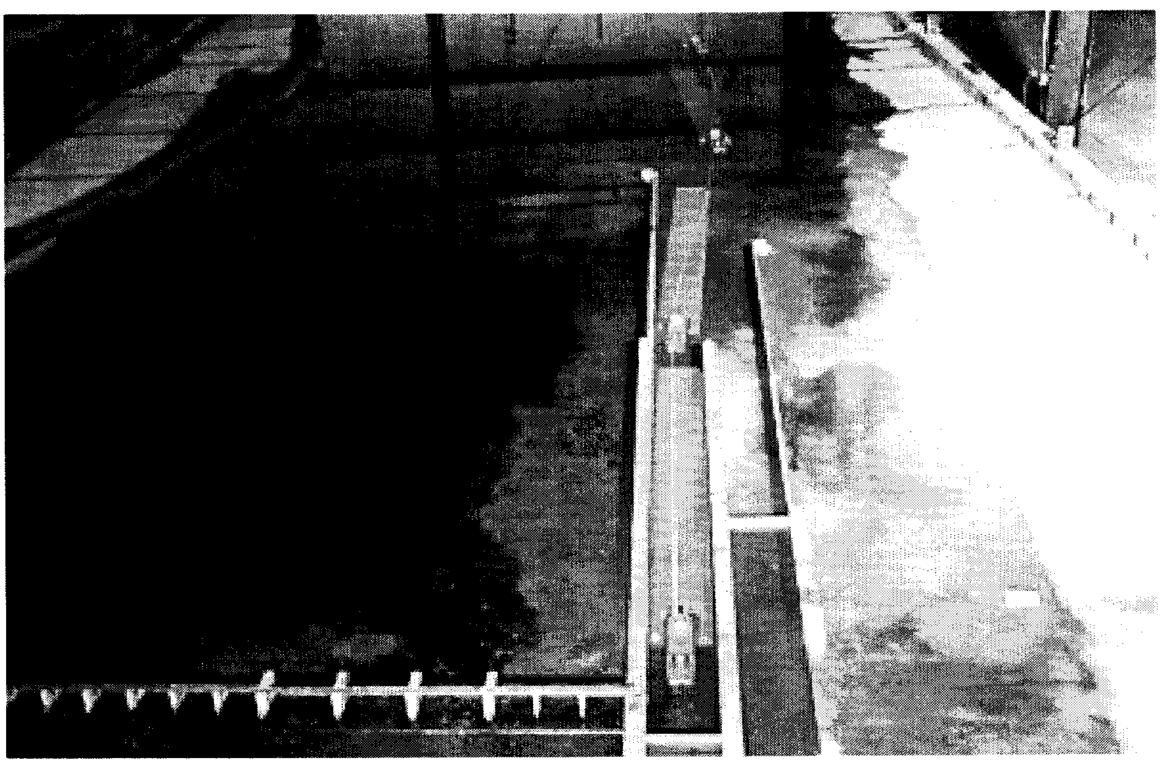


Photo 24. Lock Location 3, Plan A, looking downstream, discharge 162,000 cfs, showing path of downbound tow leaving 1,200-ft lock

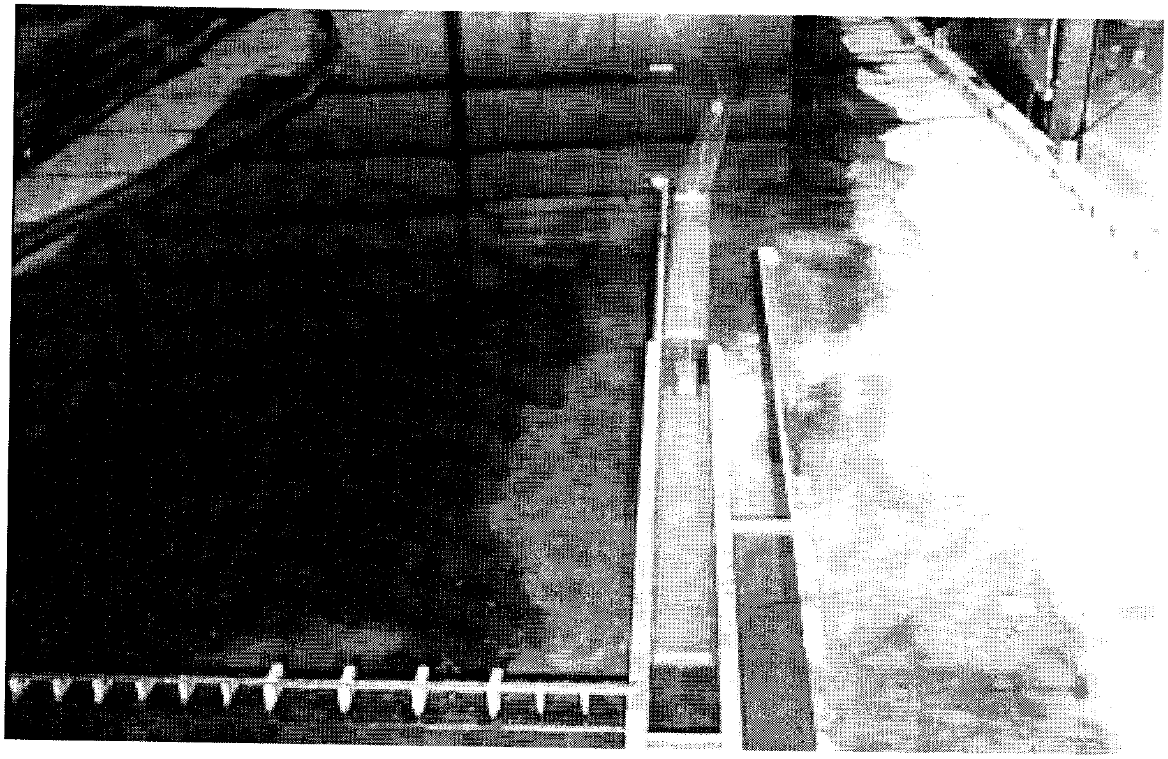


Photo 25. Lock Location 3, Plan A, looking downstream, discharge 162,000 cfs, showing path of upbound tow approaching 1,200-ft lock

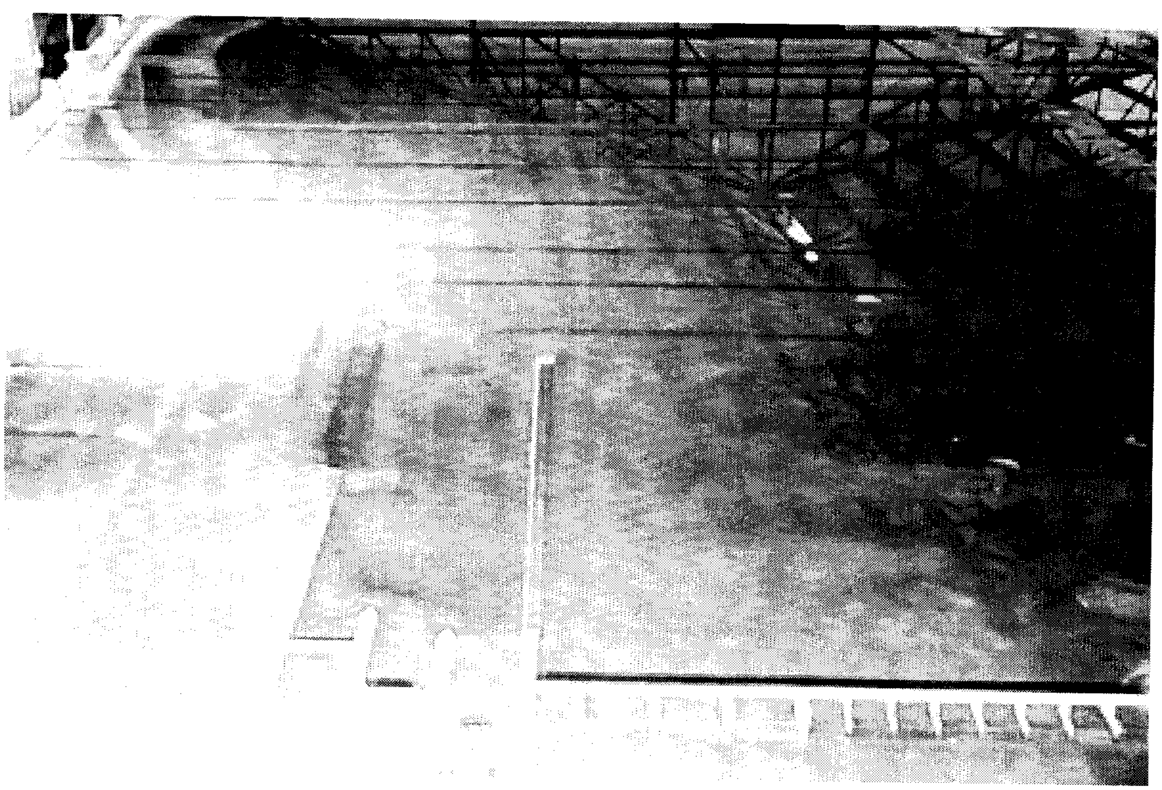


Photo 26. Lock Location 4 Plan A, looking upstream, showing upper lock approach

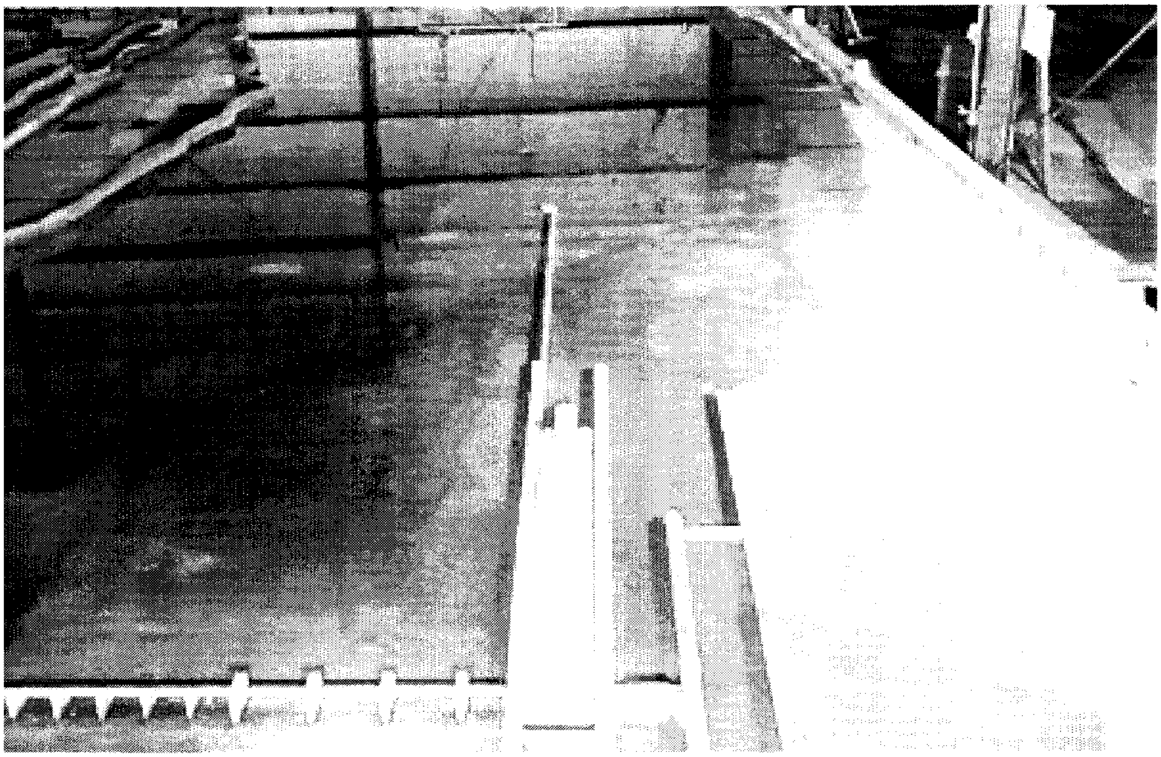


Photo 27. Lock Location 4, Plan A, looking downstream, showing lower lock approach

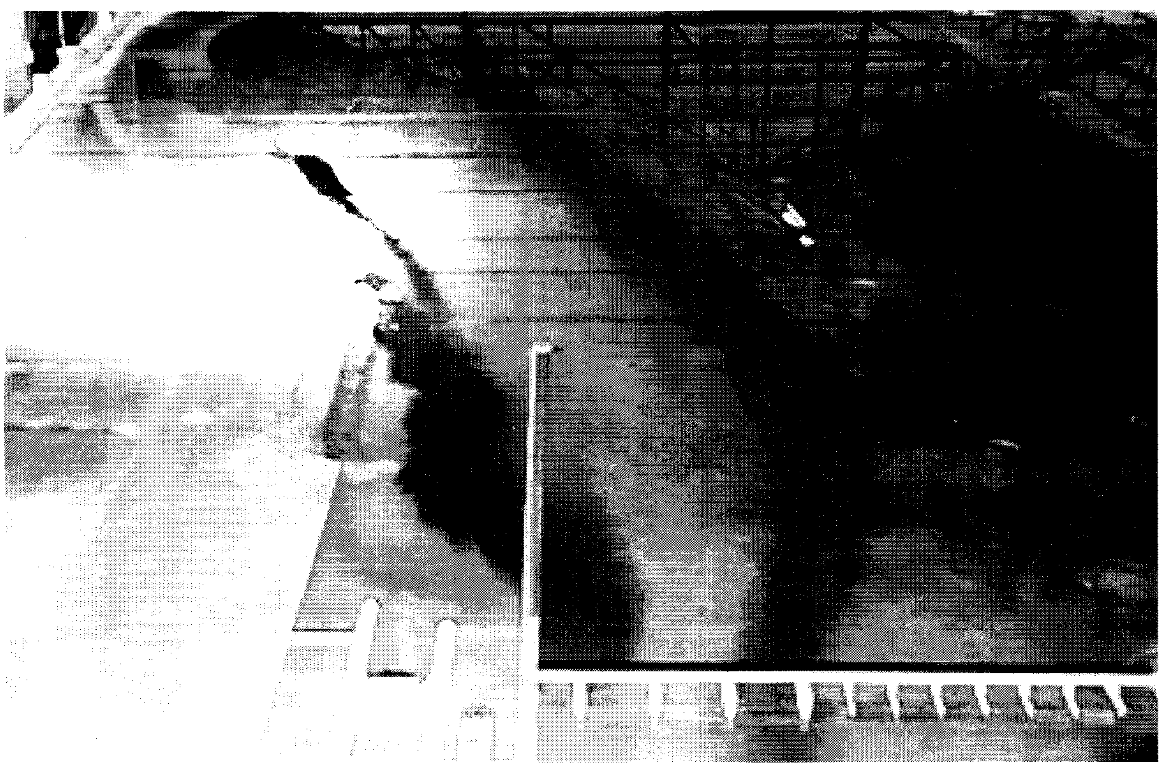


Photo 28. Lock Location 4, Plan A, looking upstream, discharge 162,000 cfs, dye showing current pattern approaching locks

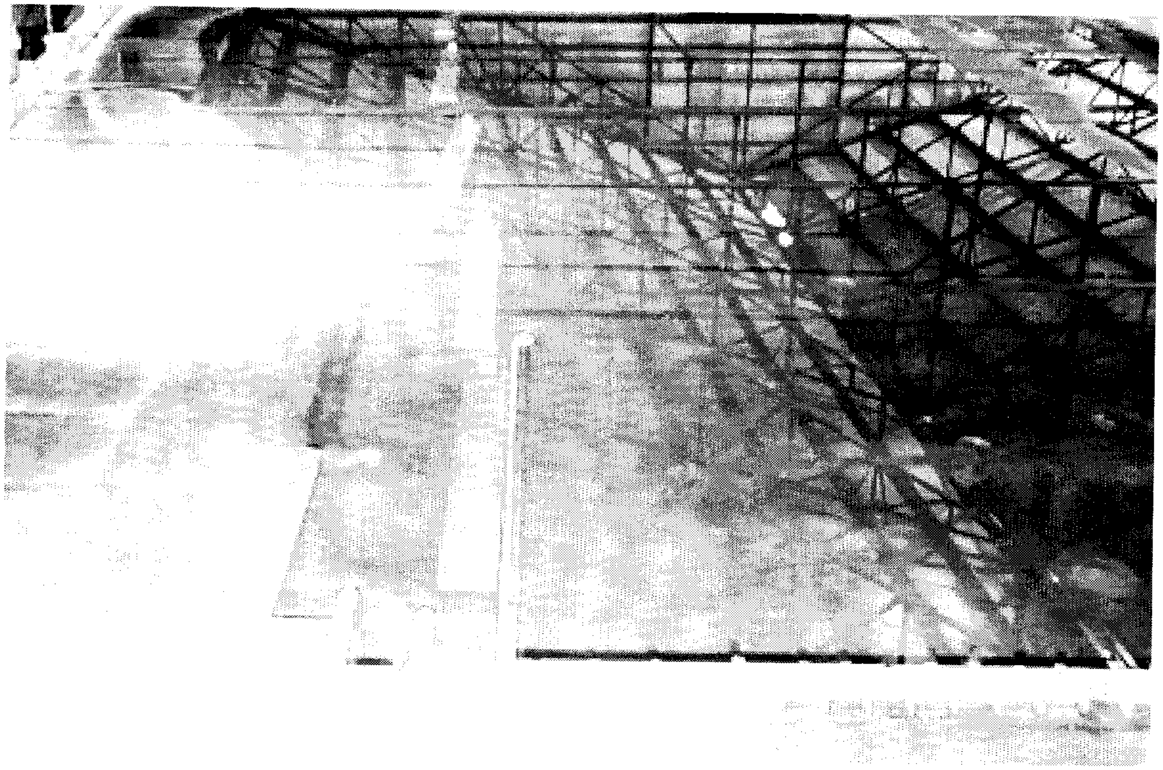


Photo 29. Lock Location 4, Plan A, looking upstream, discharge 50,000 cfs, showing path of downbound tow approaching 1,200-ft lock

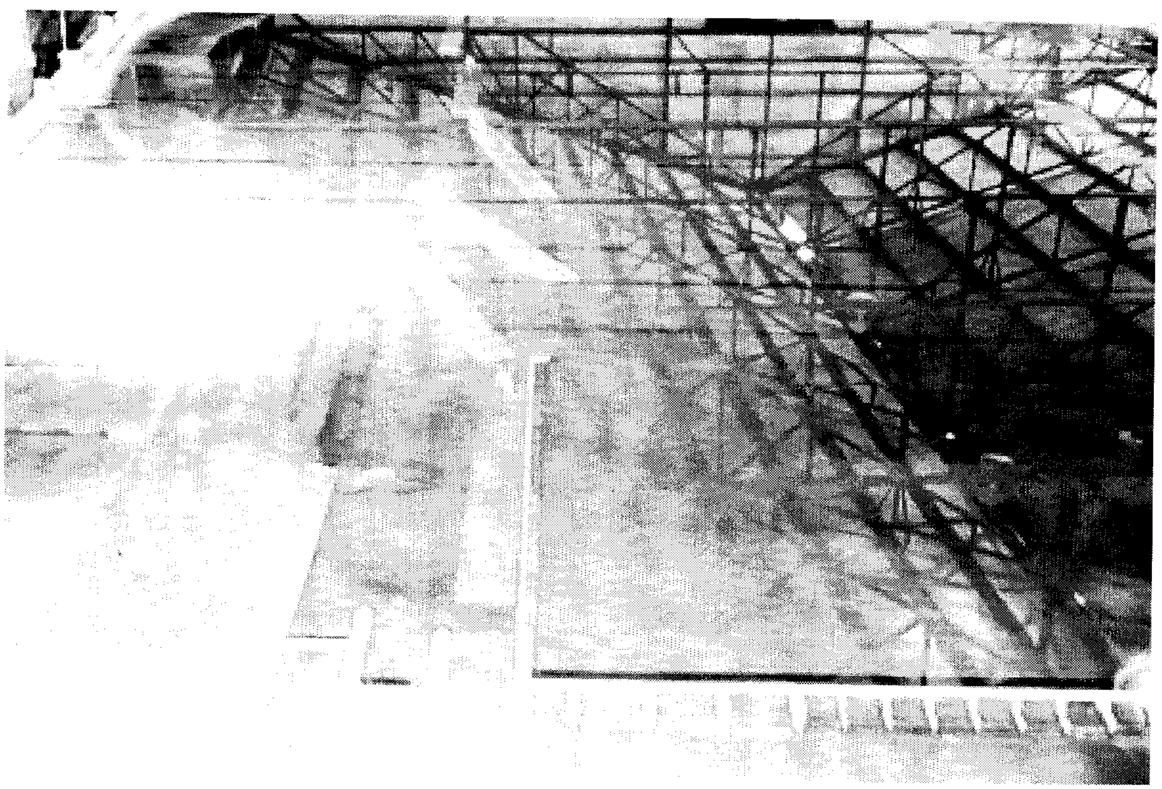


Photo 30. Lock Location 4, Plan A, looking upstream, discharge 162,000 cfs, showing path of downbound tow approaching 1,200-ft lock

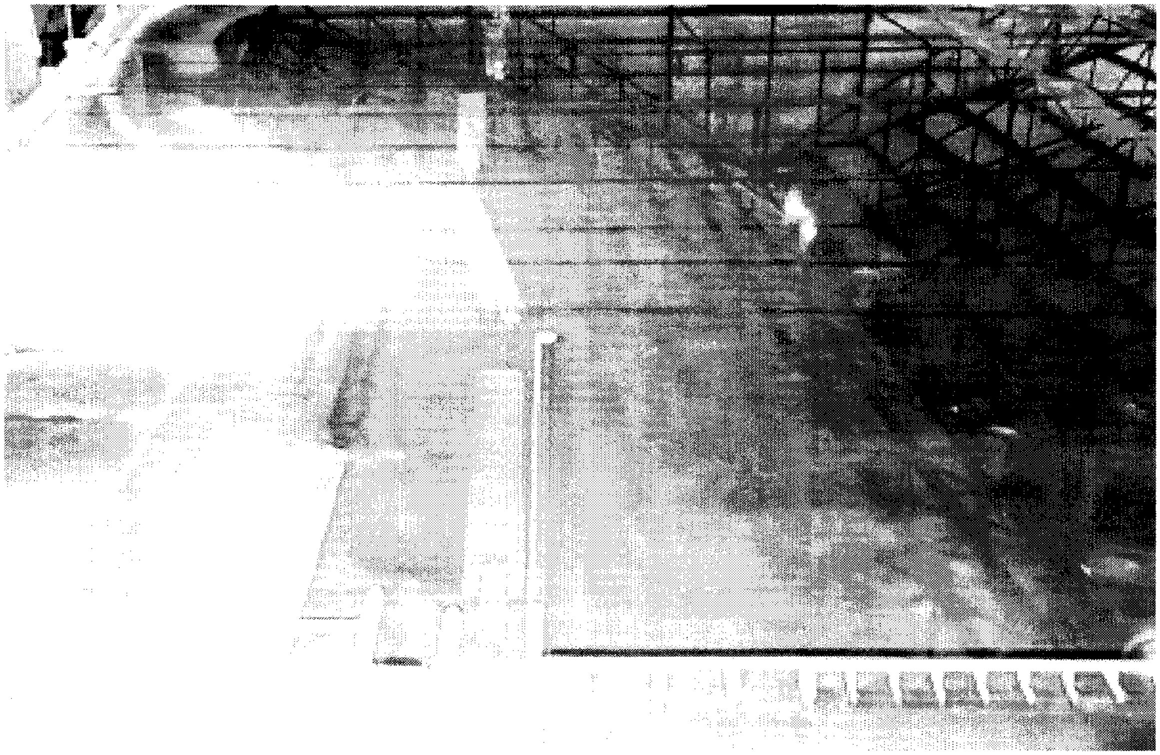


Photo 31. Lock Location 4. Plan A, looking upstream, discharge 162,000 cfs, showing path of upbound tow leaving 1,200-ft lock

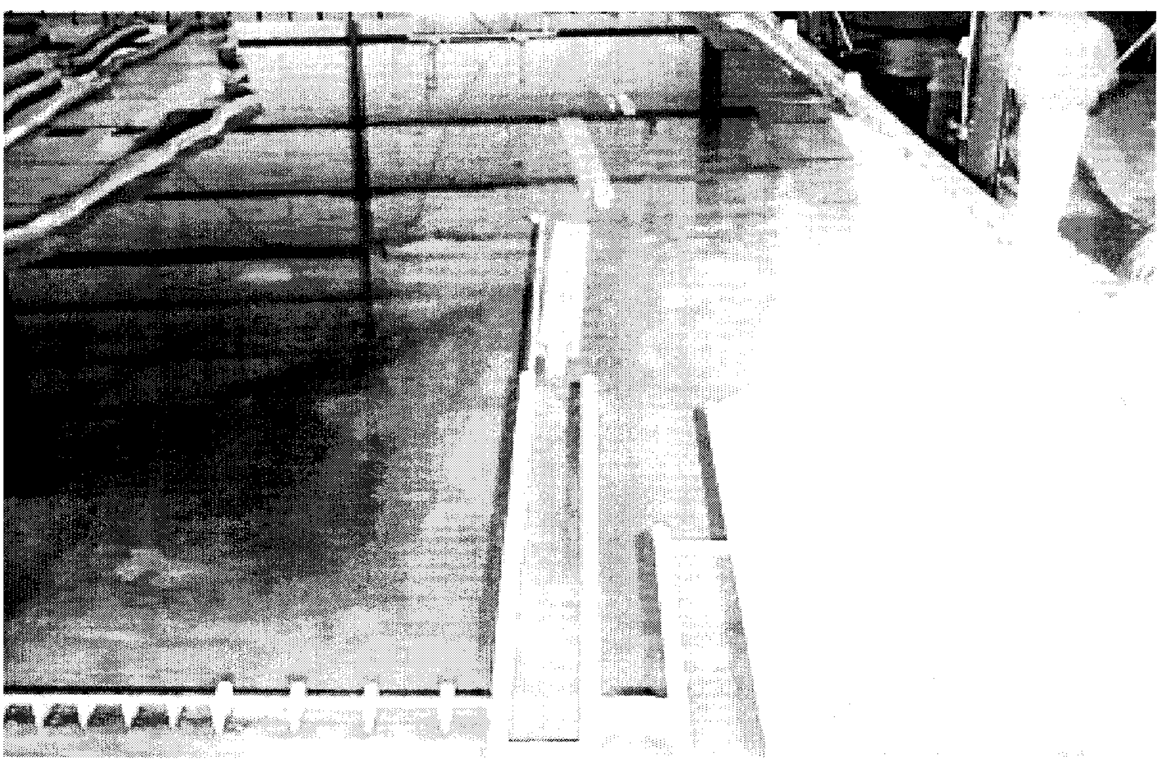


Photo 32. Lock Location 4. Plan A, looking downstream, discharge 162,000 cfs, showing path of downbound tow leaving 1,200-ft lock

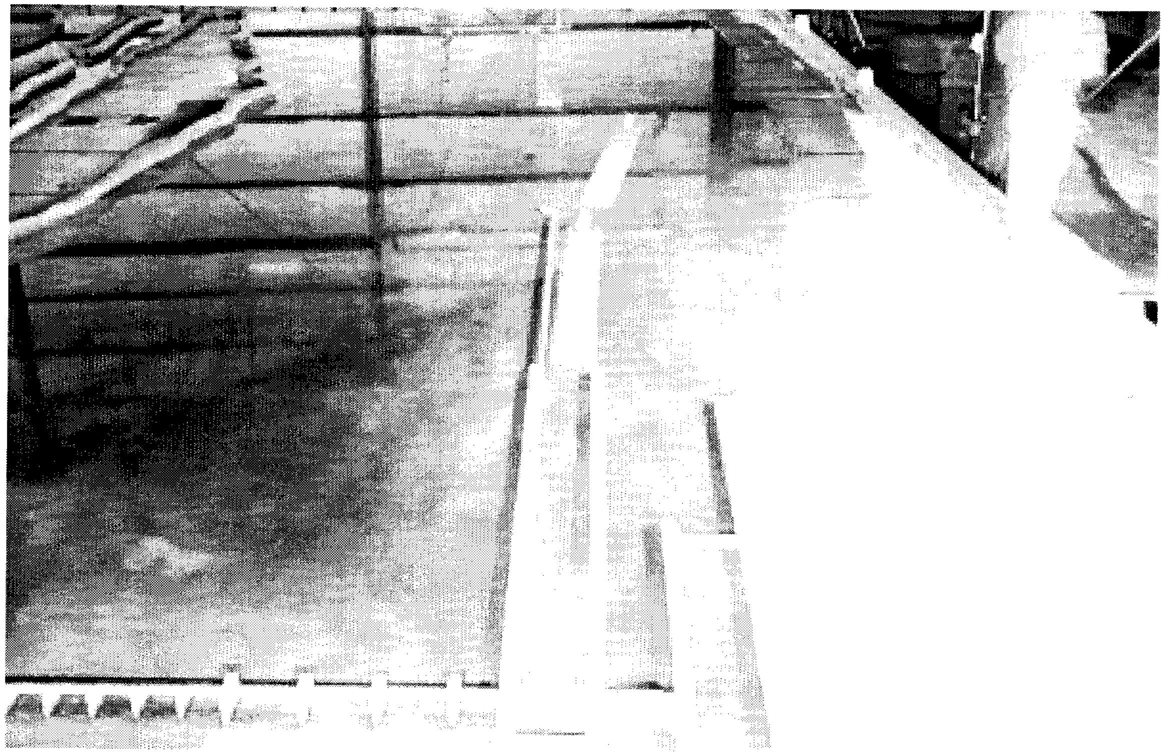
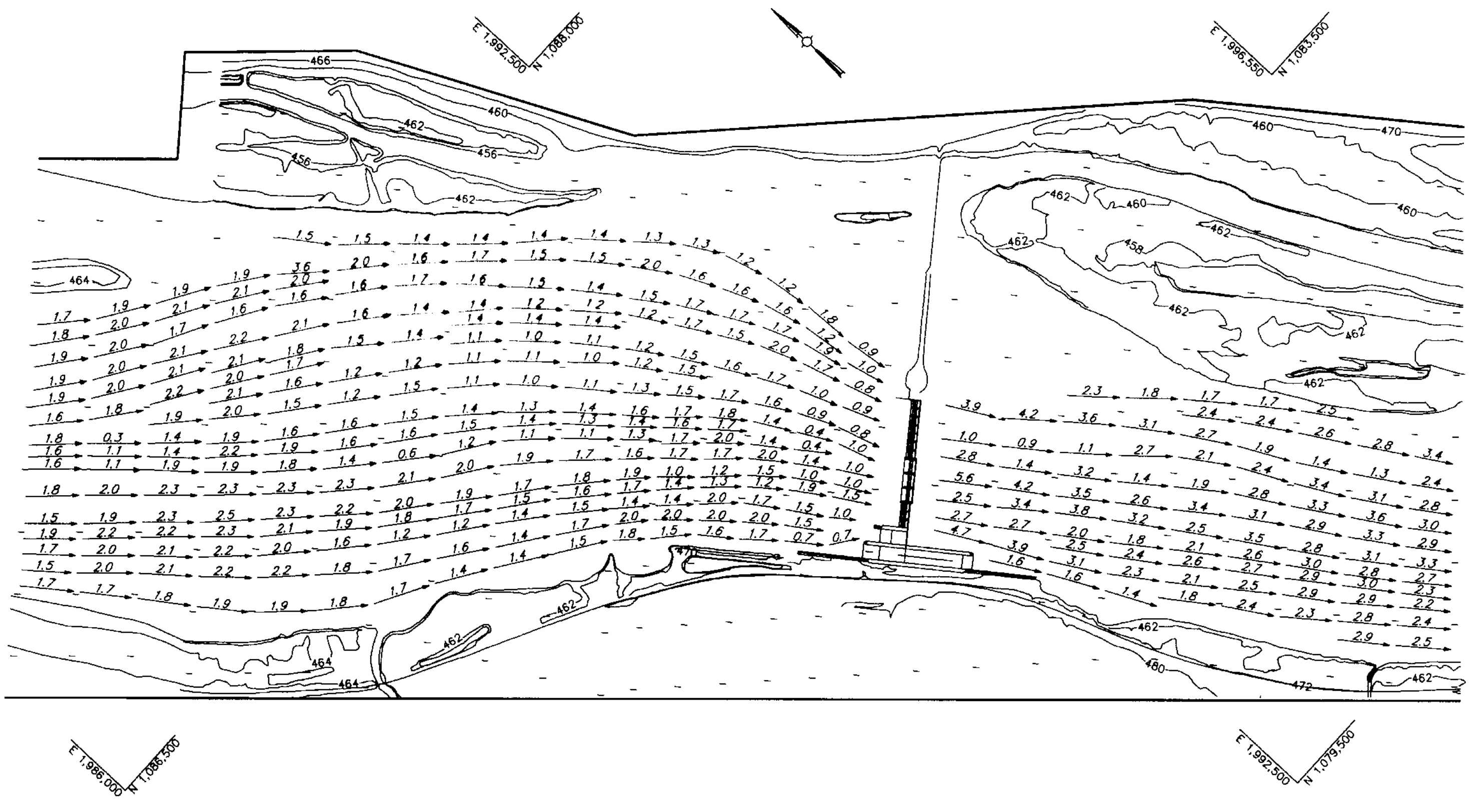


Photo 33. Lock Location 4 Plan A, looking downstream, discharge 162,000 cfs, showing path of upbound tow approaching 1,200-ft lock

LD22-022



LEGEND

3.5 — VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES IN FEET

PROTOTYPE 0 500 1000 1500 2000 2500 3000

MODEL 0 5 10 15 20 25

VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 50,000 CFS

TAILWATER EL: 451.3 FT

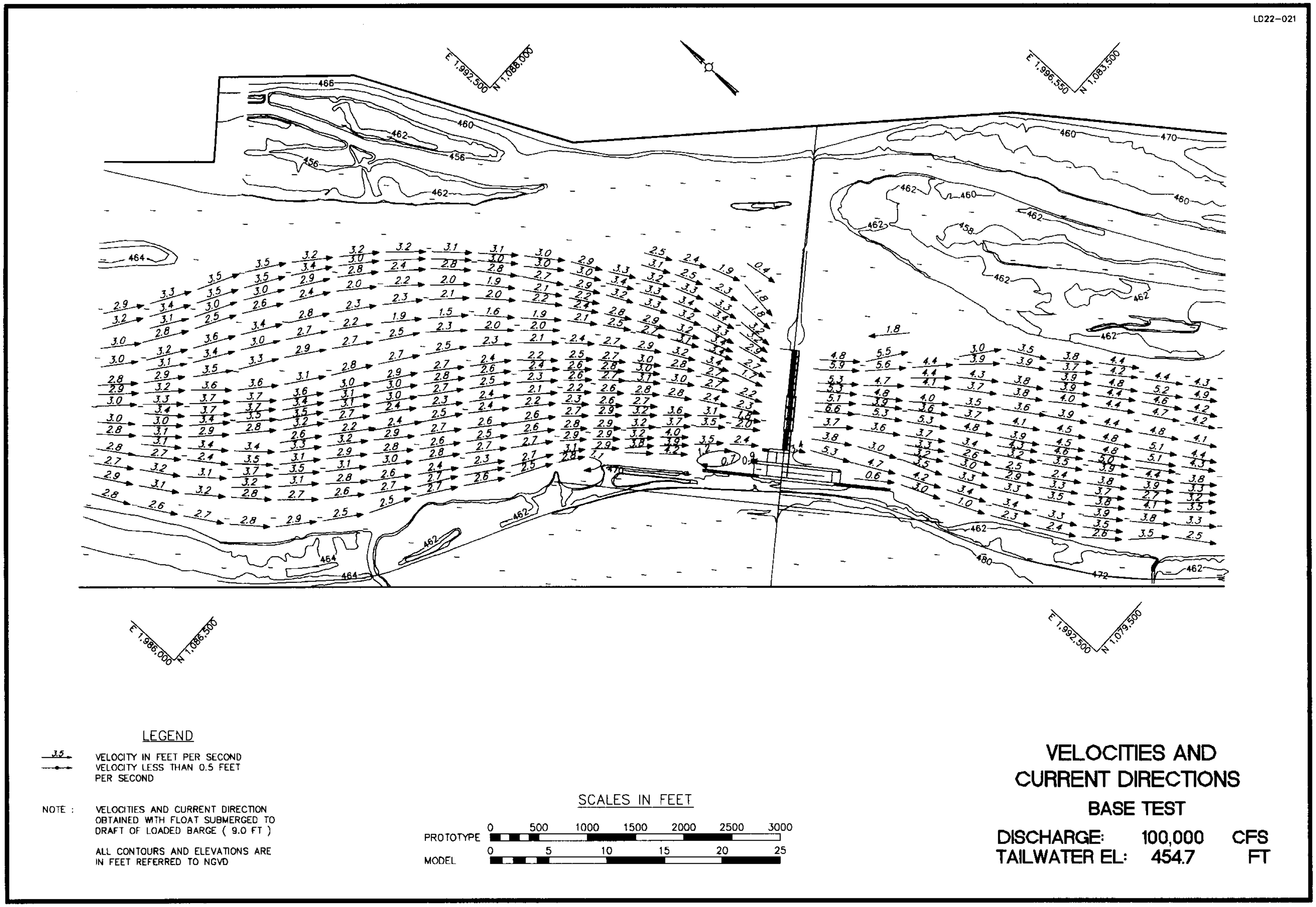
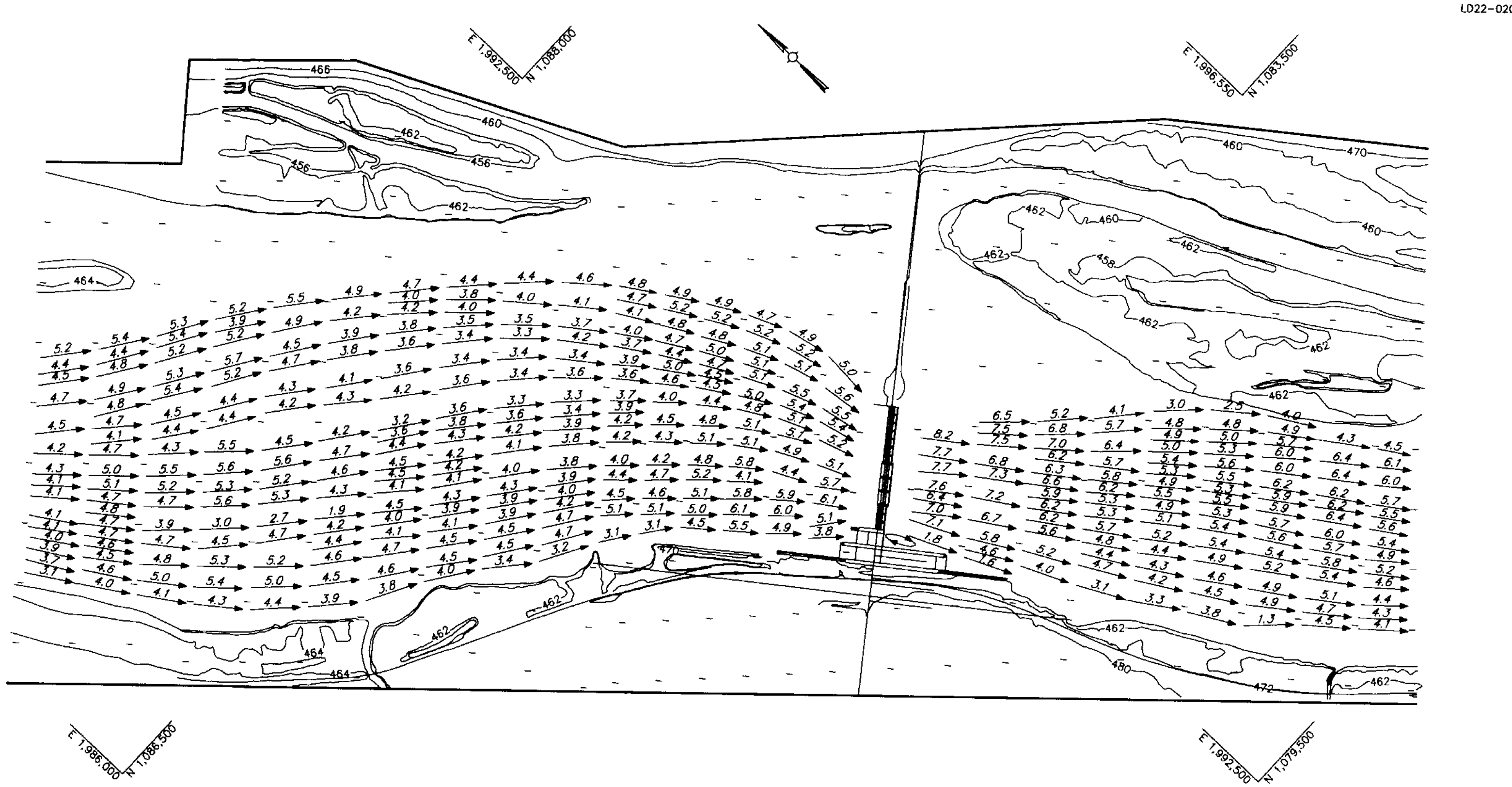

LD22-021
LEGEND
3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500 3000
MODEL 0 5 10 15 20 25
VELOCITIES AND CURRENT DIRECTIONS
BASE TEST
DISCHARGE: 100,000 CFS
TAILWATER EL: 454.7 FT

Plate 2



LEGEND

3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

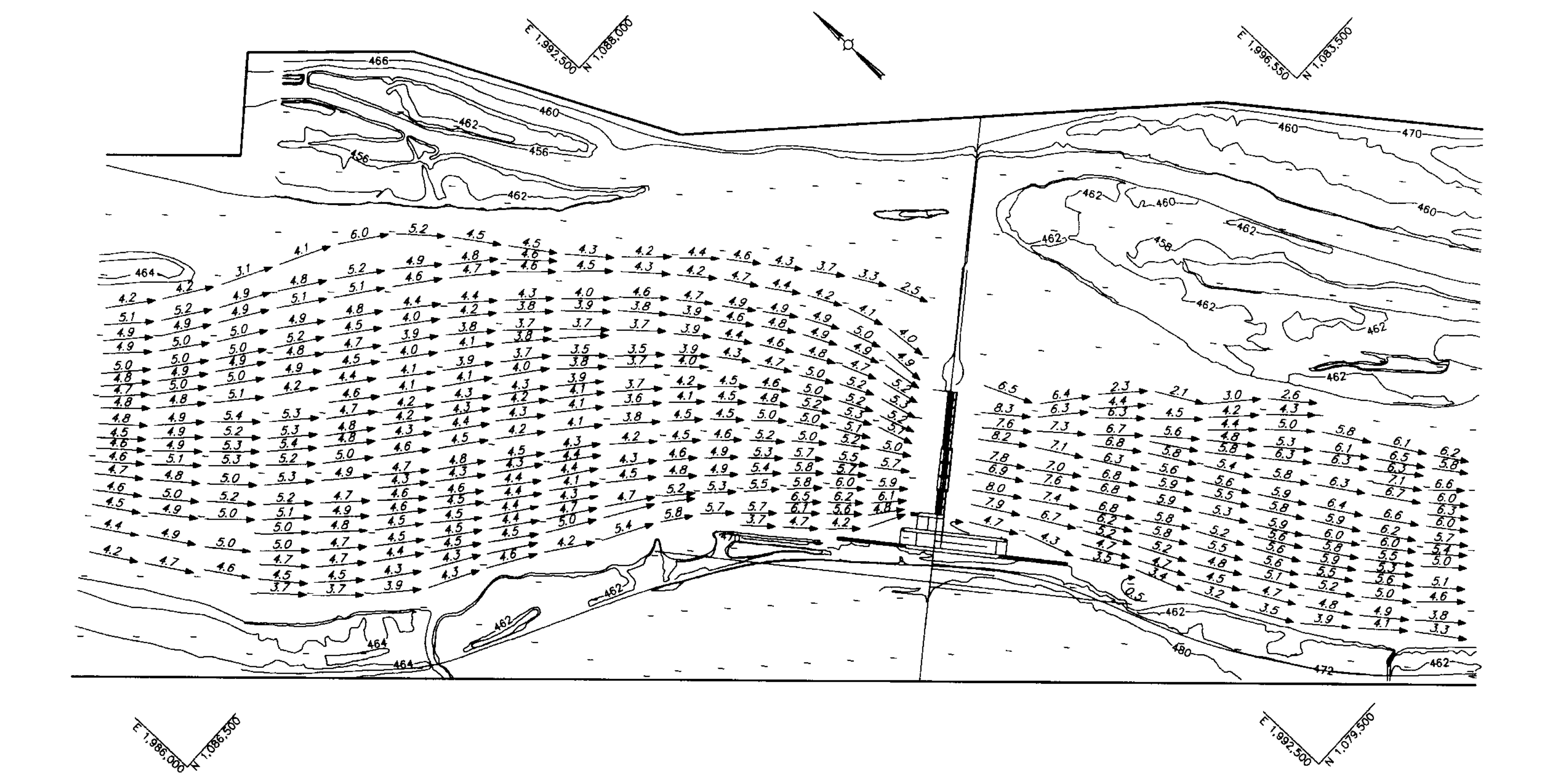
SCALES IN FEET

PROTOTYPE	0	500	1000	1500	2000	2500	3000
MODEL	0	5	10	15	20	25	

VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 162,000 CFS
TAILWATER EL: 459.5 FT



LEGEND

3.5 (arrow)	VELOCITY IN FEET PER SECOND
(dot arrow)	VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES IN FEET

PROTOTYPE 0 500 1000 1500 2000 2500 3000

MODEL 0 5 10 15 20 25

VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 220,000 CFS
TAILWATER EL: 462.8 FT

Plate 4

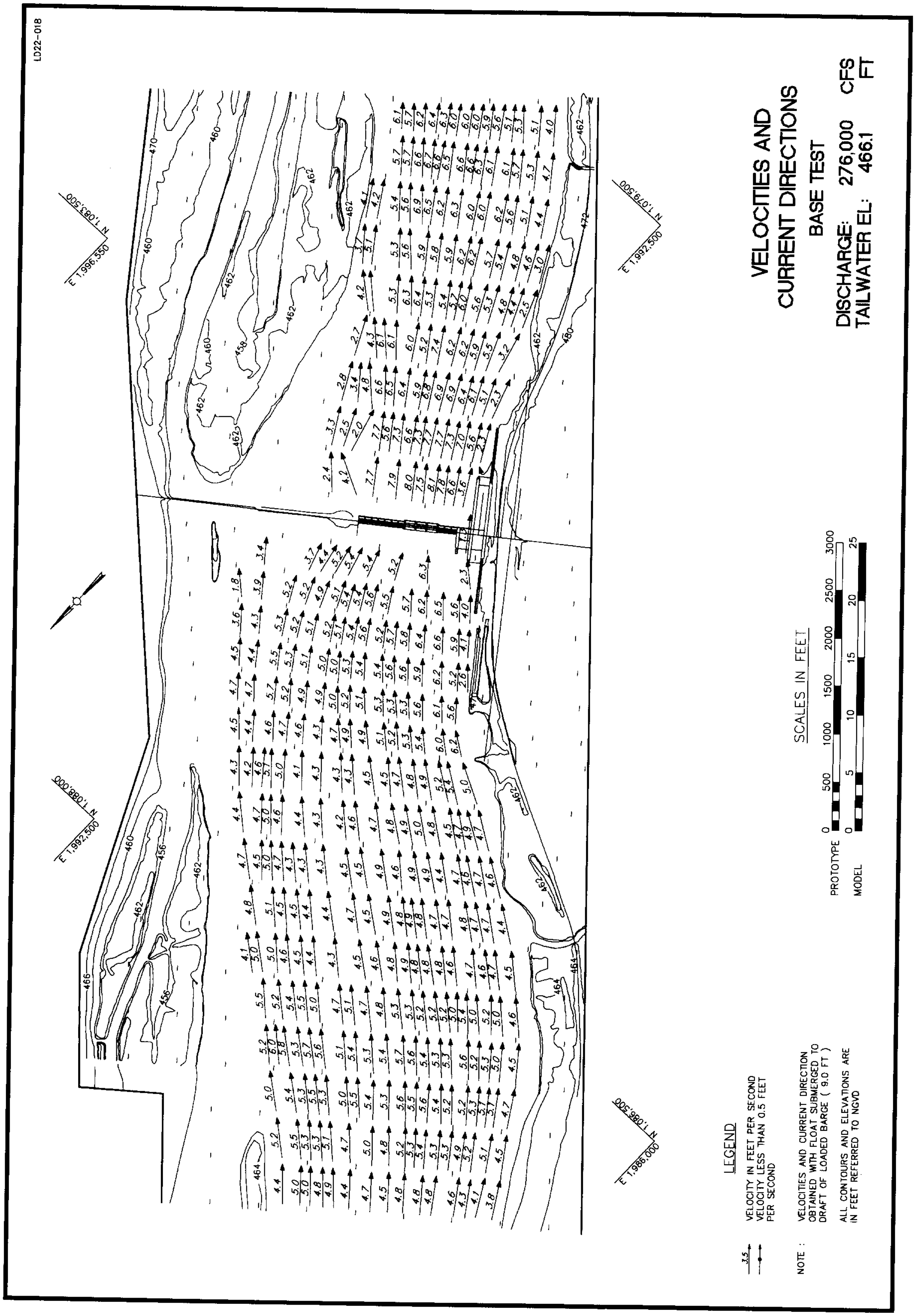

LD22-018
VELOCITIES AND CURRENT DIRECTIONS
BASE TEST
DISCHARGE: 276,000 CFS
TAILWATER EL: 466.1 FT
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES IN FEET
PROTOTYPE
MODEL

Plate 5

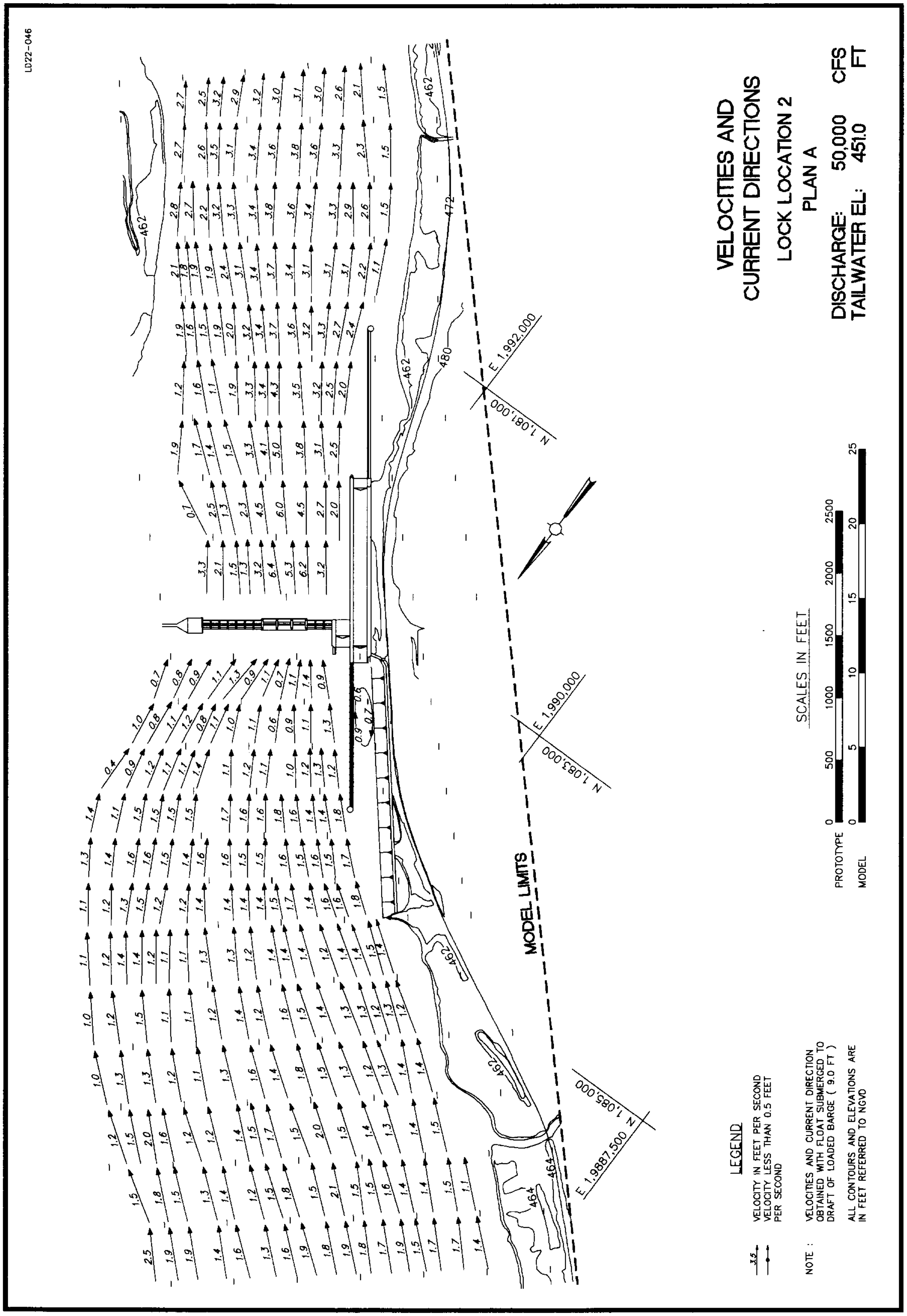

LD22-046
VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN A
DISCHARGE: 50,000 CFS
TAILWATER EL: 451.0 FT
MODEL LIMITS
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
E 1,992,000
N 1,081,000
E 1,990,000
N 1,083,000
E 1,9887,500
N 1,085,000

Plate 6

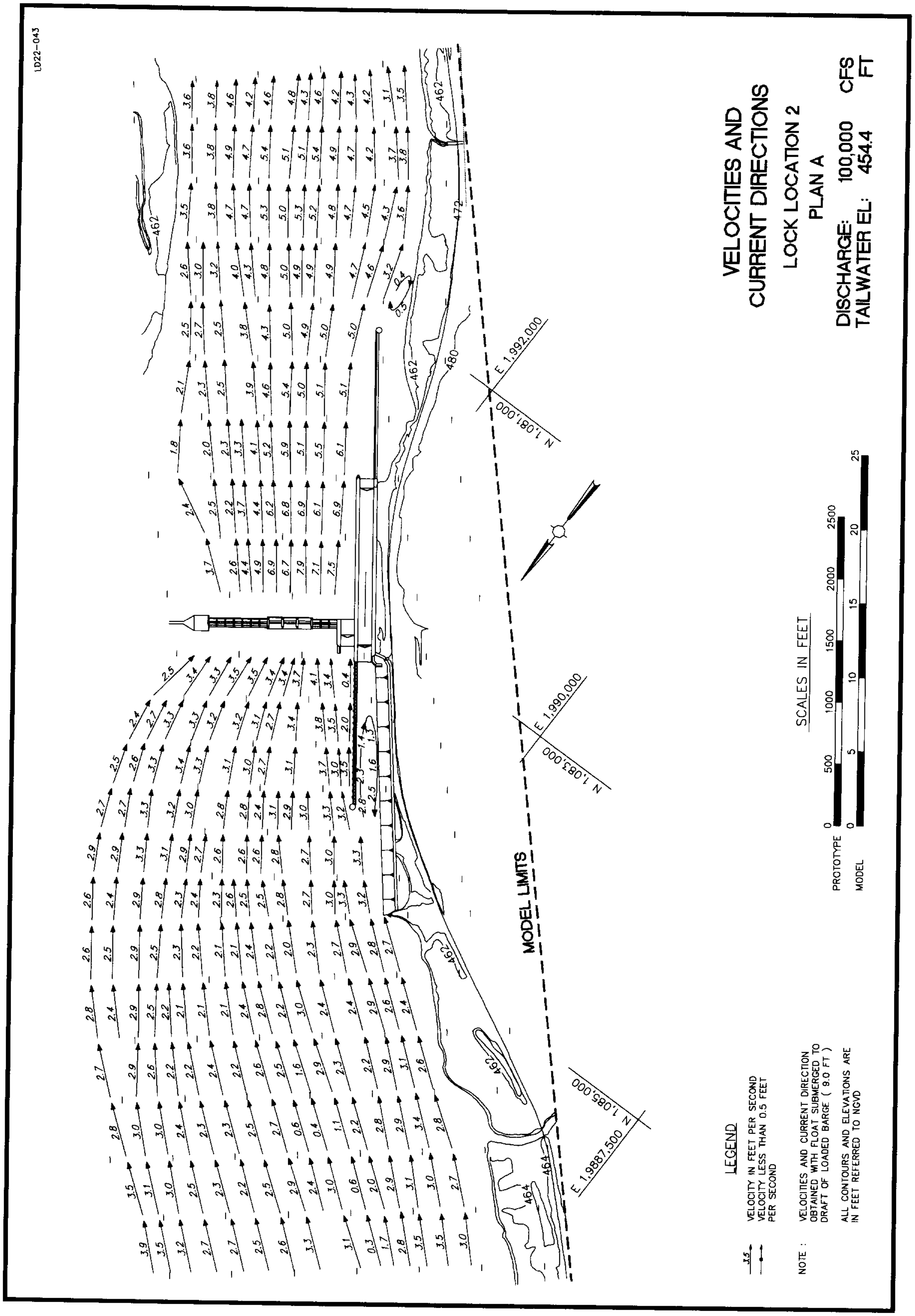

LD22-043
VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN A
DISCHARGE: 100,000 CFS
TAILWATER EL: 454.4 FT
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
MODEL LIMITS
E 1,992,000
N 1,081,000
E 1,990,000
N 1,083,000
E 1,9887,500
N 1,085,000

Plate 7

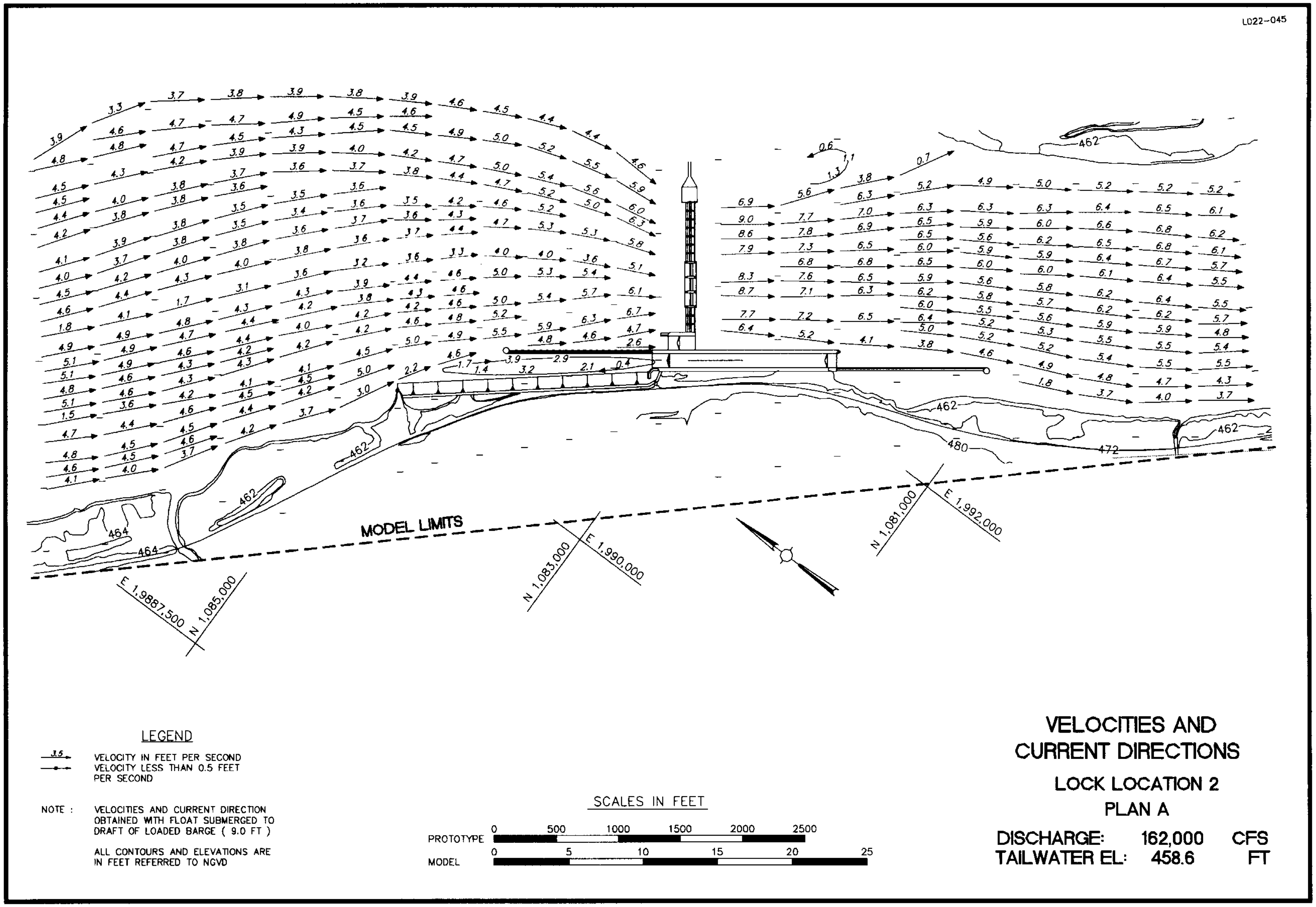

L022-045
MODEL LIMITS
E 1,9887,500
N 1,085,000
N 1,083,000
E 1,990,000
N 1,081,000
E 1,992,000
LEGEND
3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN A
DISCHARGE: 162,000 CFS
TAILWATER EL: 458.6 FT

Plate 8

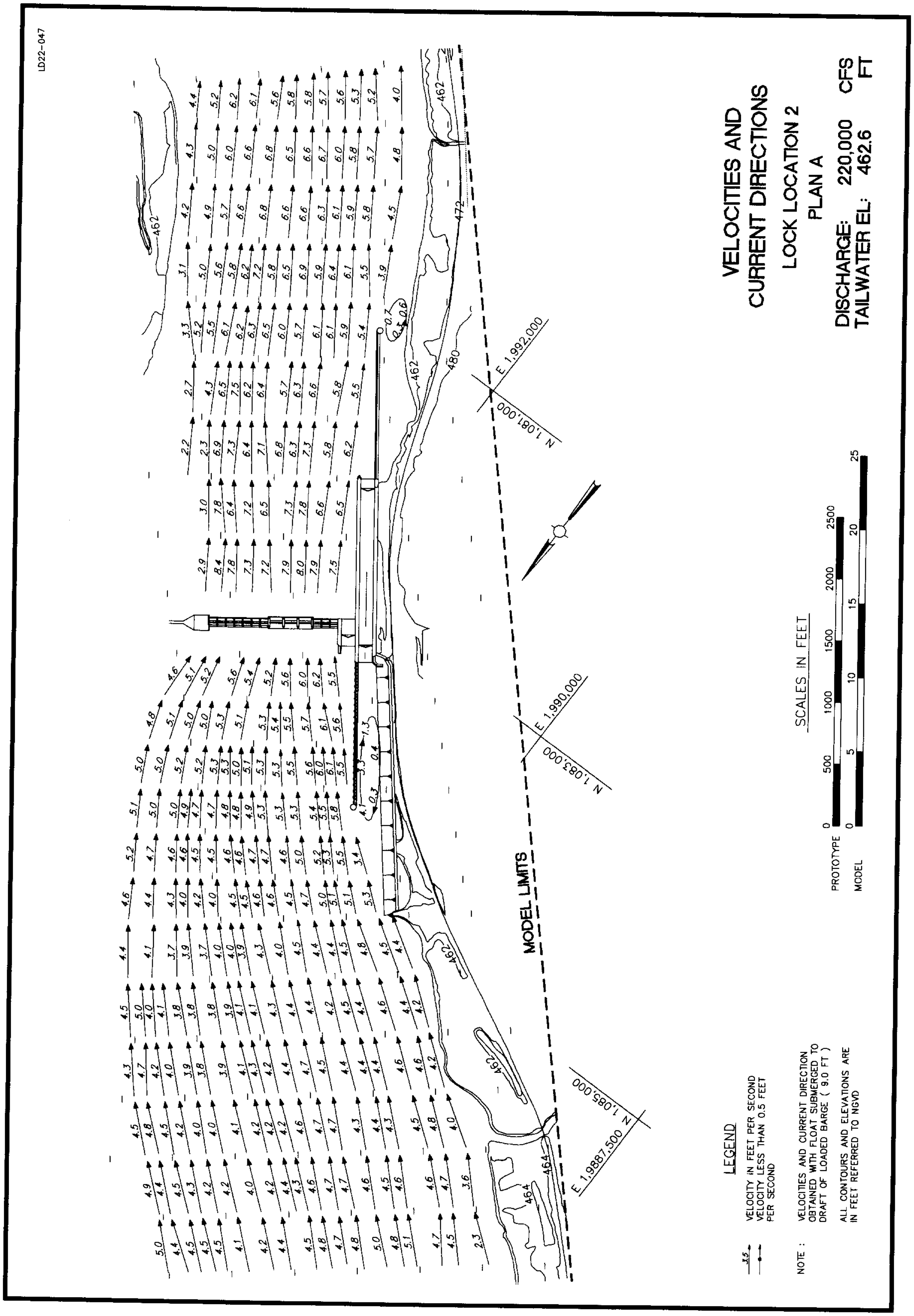
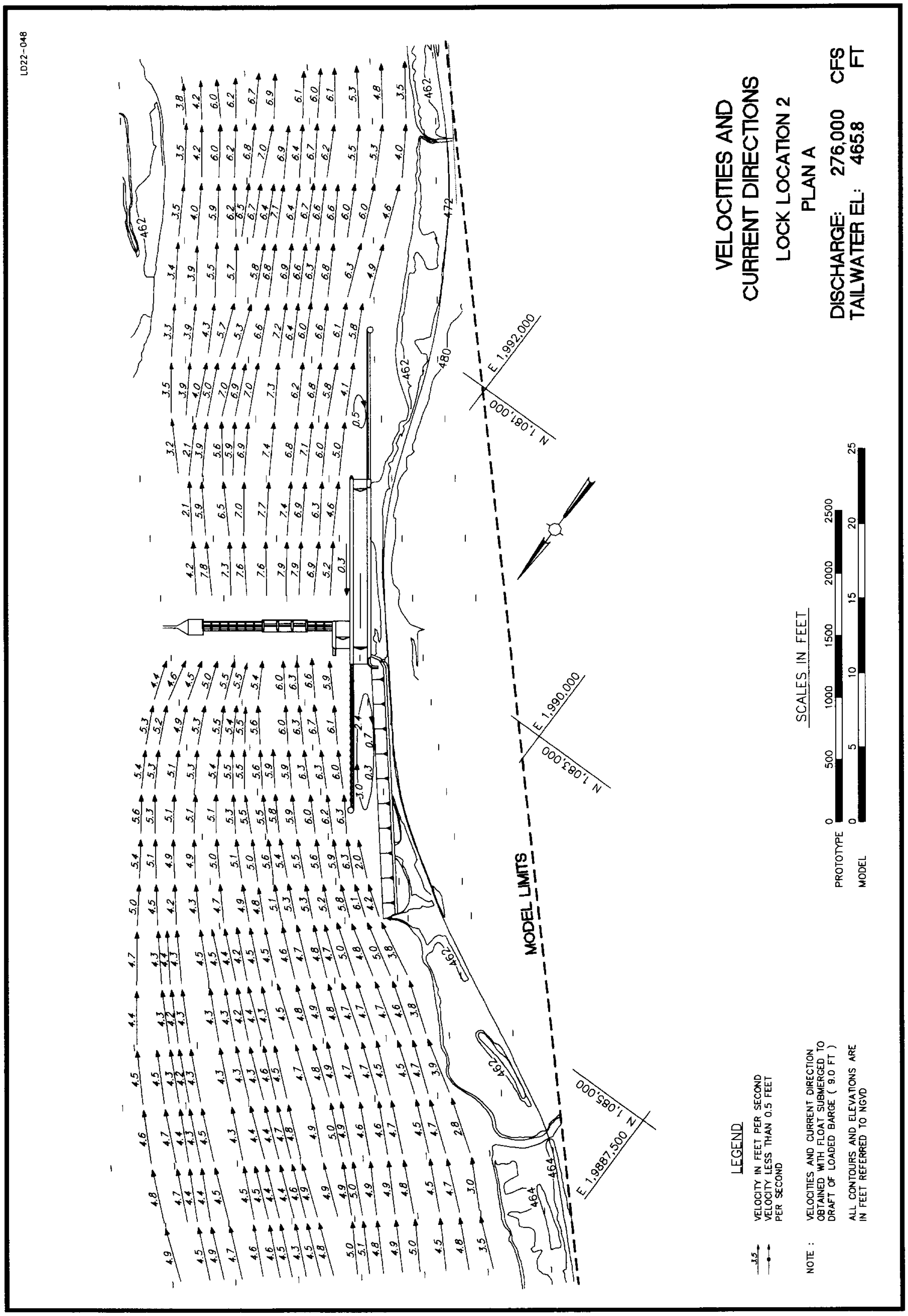
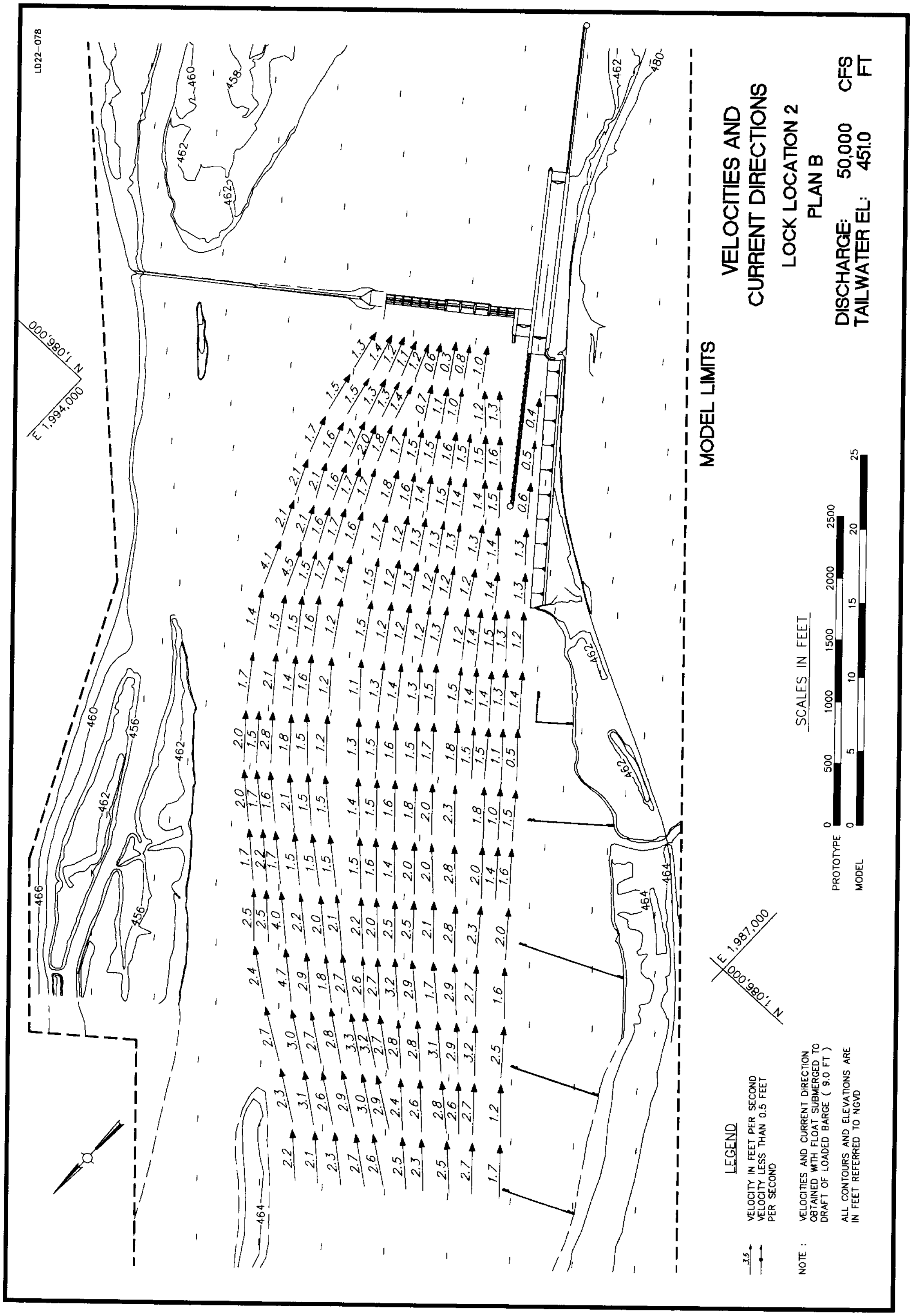

LD22-047
VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN A
DISCHARGE: 220,000 CFS
TAILWATER EL: 462.6 FT
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
MODEL LIMITS
E 1,992,000
N 1,081,000
E 1,990,000
N 1,083,000
N 1,085,000
E 1,9887,500

Plate 9

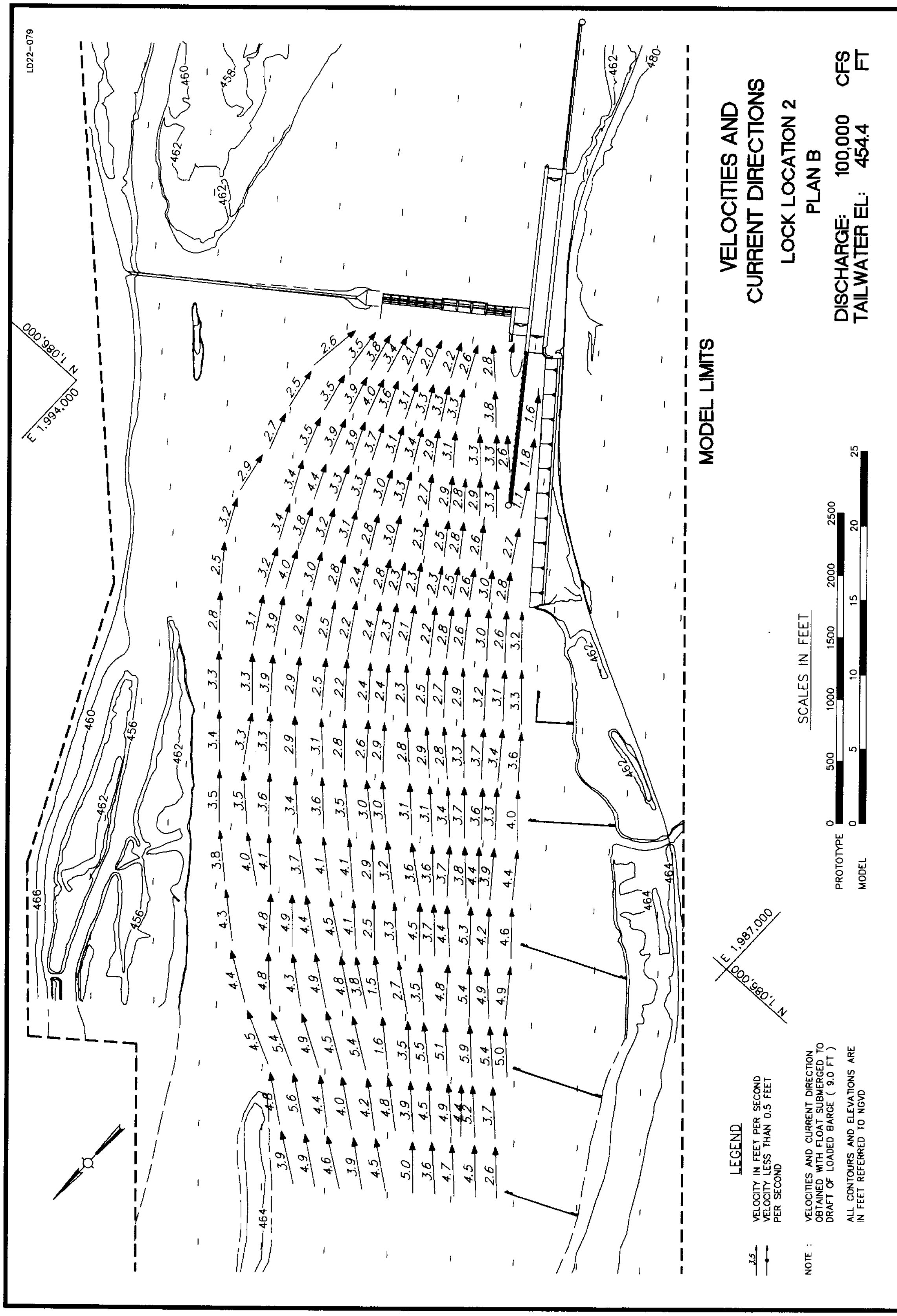


LD22-048
VELOCITIES AND
CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN A
DISCHARGE: 276,000 CFS
TAILWATER EL: 465.8 FT
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
LEGEND
3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
MODEL LIMITS
E 1,992,000
N 1,081,000
E 1,990,000
N 1,083,000
N 1,085,000
E 1,9887,500

Plate 10



L022-078
VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN B
DISCHARGE: 50,000 CFS
TAILWATER EL: 451.0 FT
MODEL LIMITS
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
E 1,994,000
N 1,086,000
E 1,987,000
N 1,086,000



LD22-079
N 1,086,000
E 1,994,000
E 1,987,000
N 1,086,000
MODEL LIMITS
VELOCITIES AND
CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN B
DISCHARGE: 100,000 CFS
TAILWATER EL: 454.4 FT
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
LEGEND
3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

Plate 12

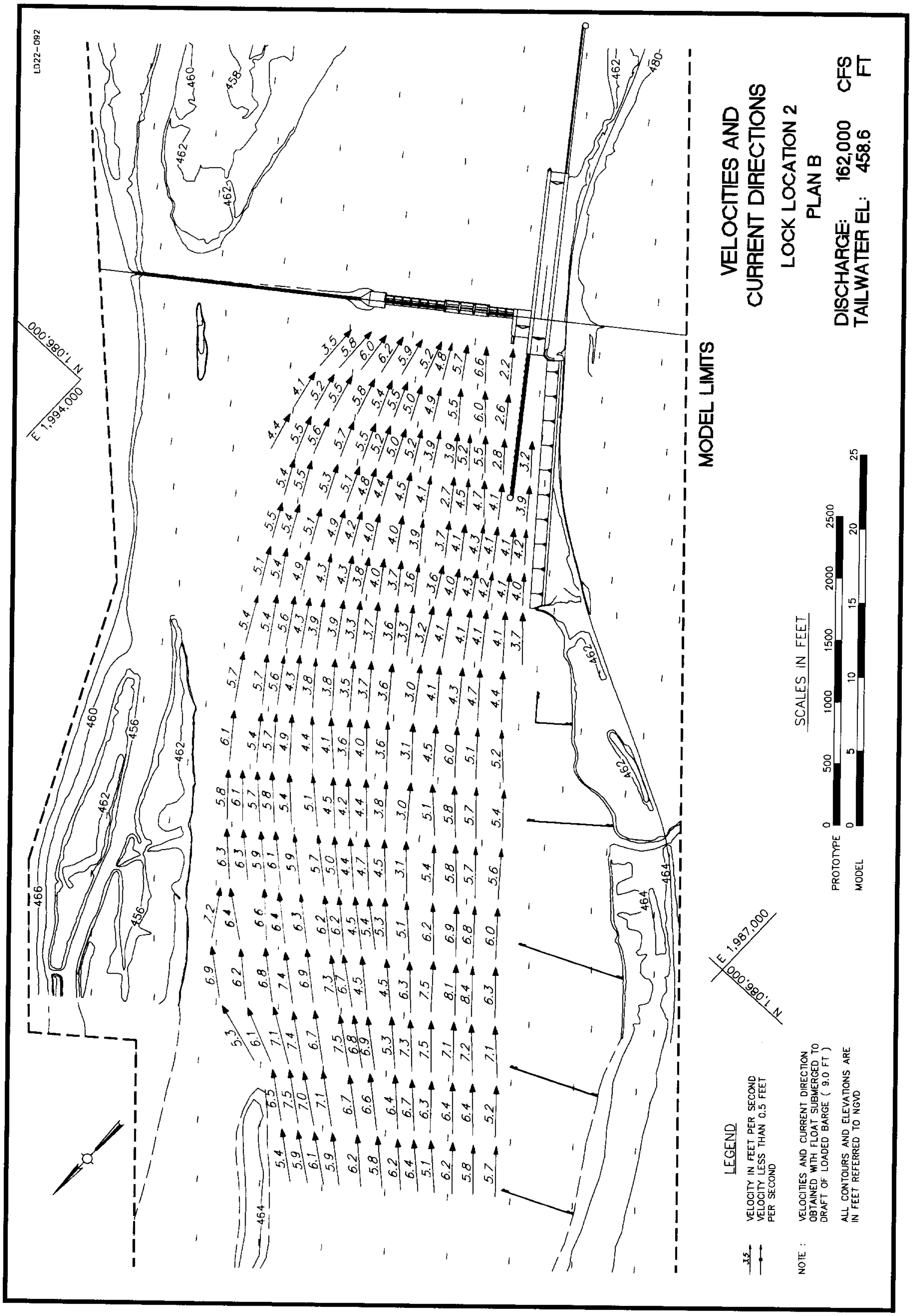

VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN B
DISCHARGE: 162,000 CFS
TAILWATER EL: 458.6 FT
MODEL LIMITS
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
N 1,086,000
E 1,994,000
E 1,987,000
LD22-092

Plate 13

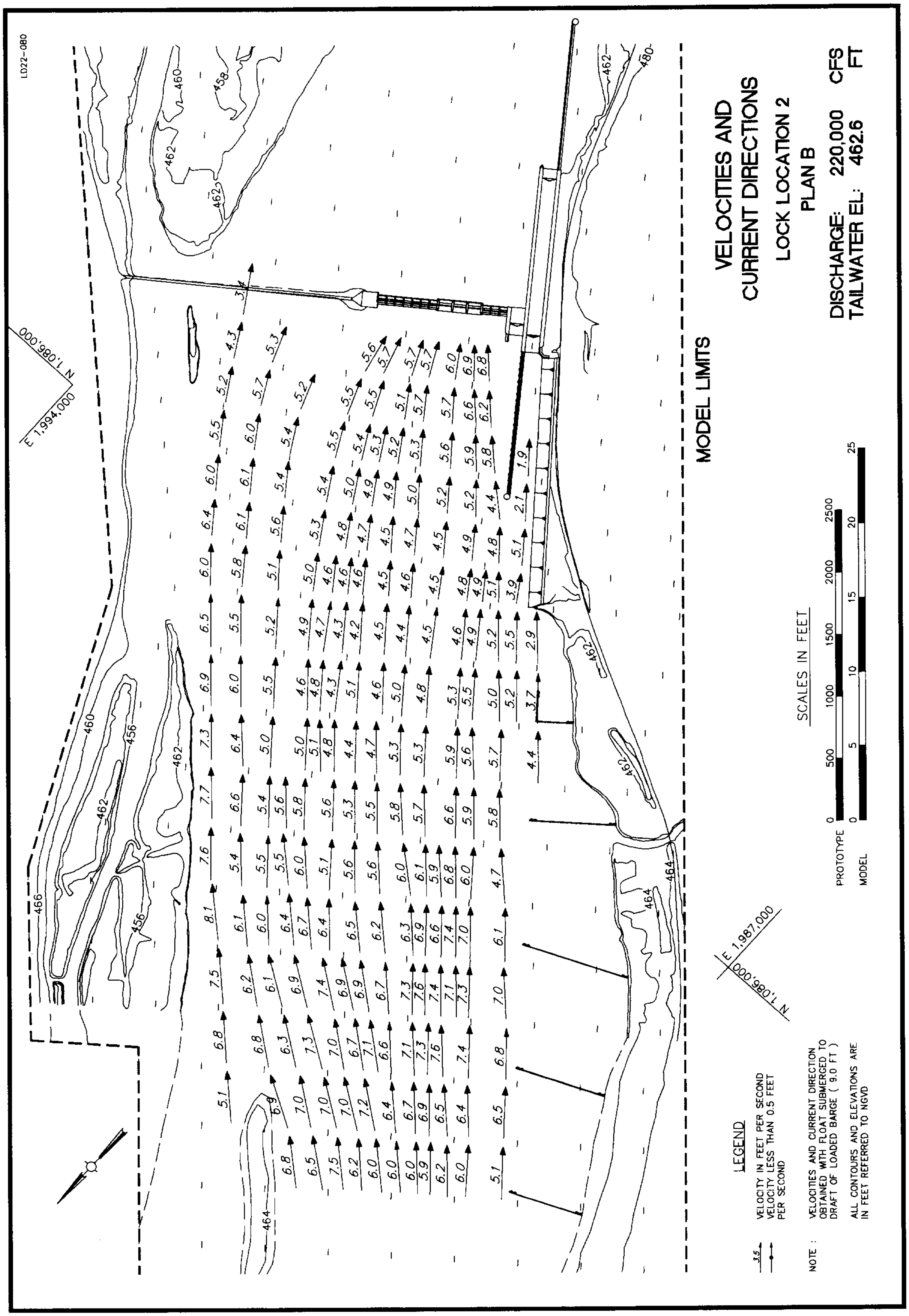
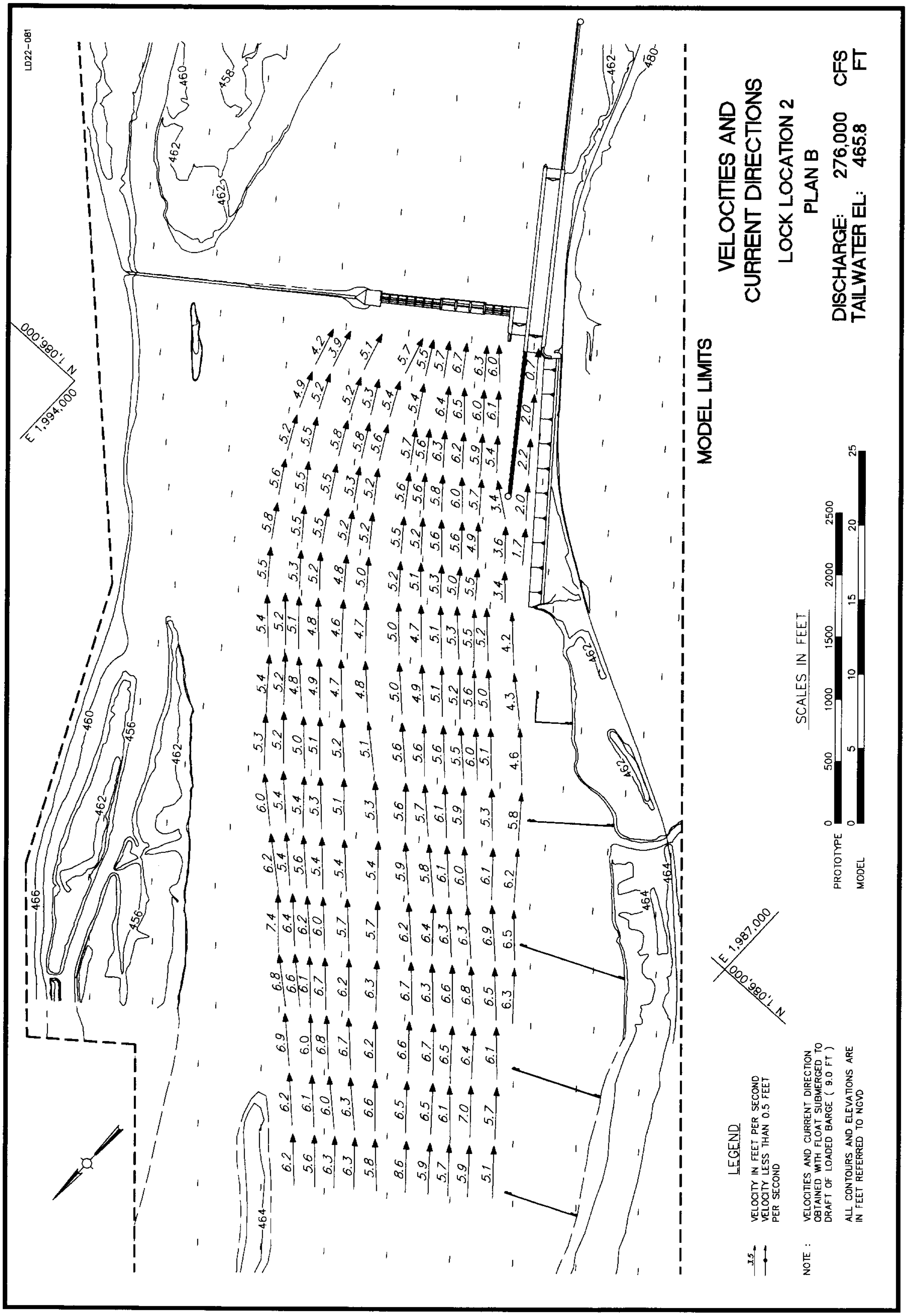
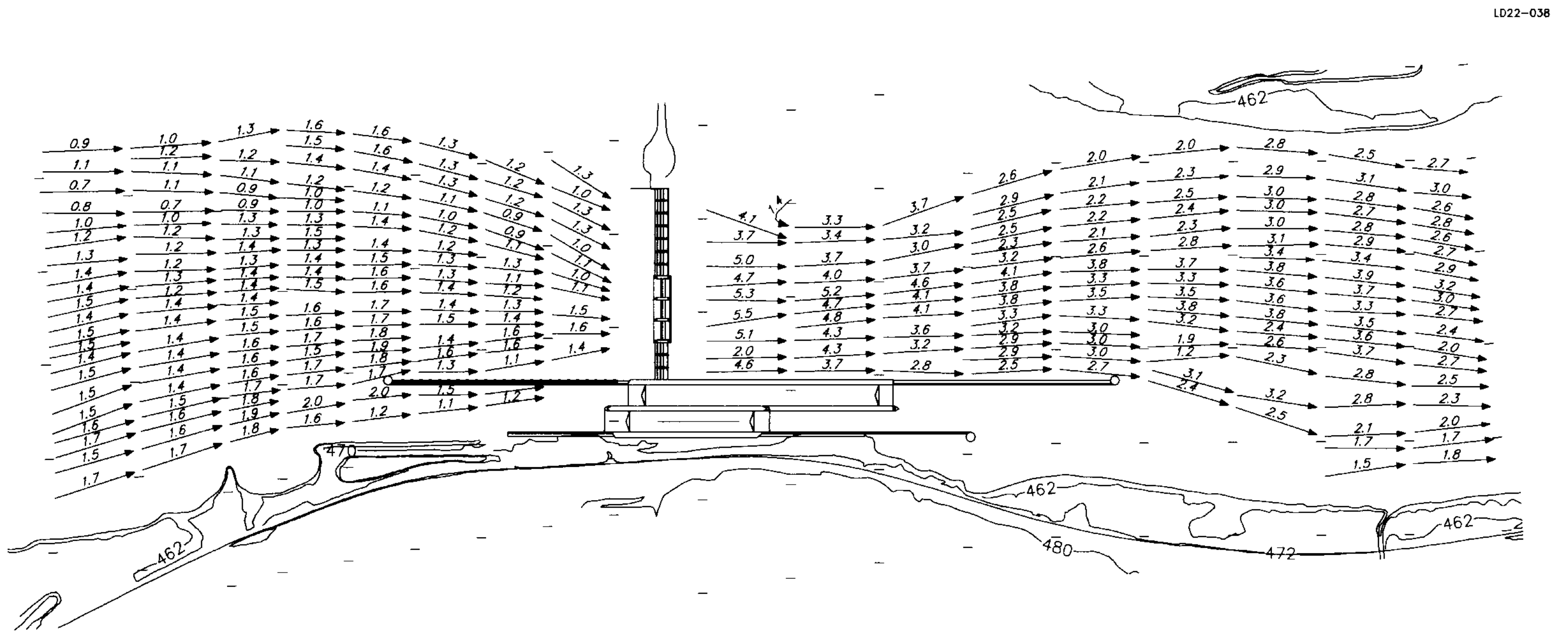

VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN B
DISCHARGE: 220,000 CFS
TAILWATER EL: 462.6 FT
MODEL LIMITS
LD22-080
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
N 1,086,000
E 1,994,000
E 1,987,000

Plate 14



VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 2
PLAN B
DISCHARGE: 276,000 CFS
TAILWATER EL: 465.8 FT
MODEL LIMITS
LEGEND
3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES IN FEET
PROTOTYPE 0 500 1000 1500 2000 2500
MODEL 0 5 10 15 20 25
E 1,994,000
N 1,086,000
E 1,987,000
N 1,086,000
LD22-081

Plate 15



LEGEND

3.5 — VELOCITY IN FEET PER SECOND
—•— VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

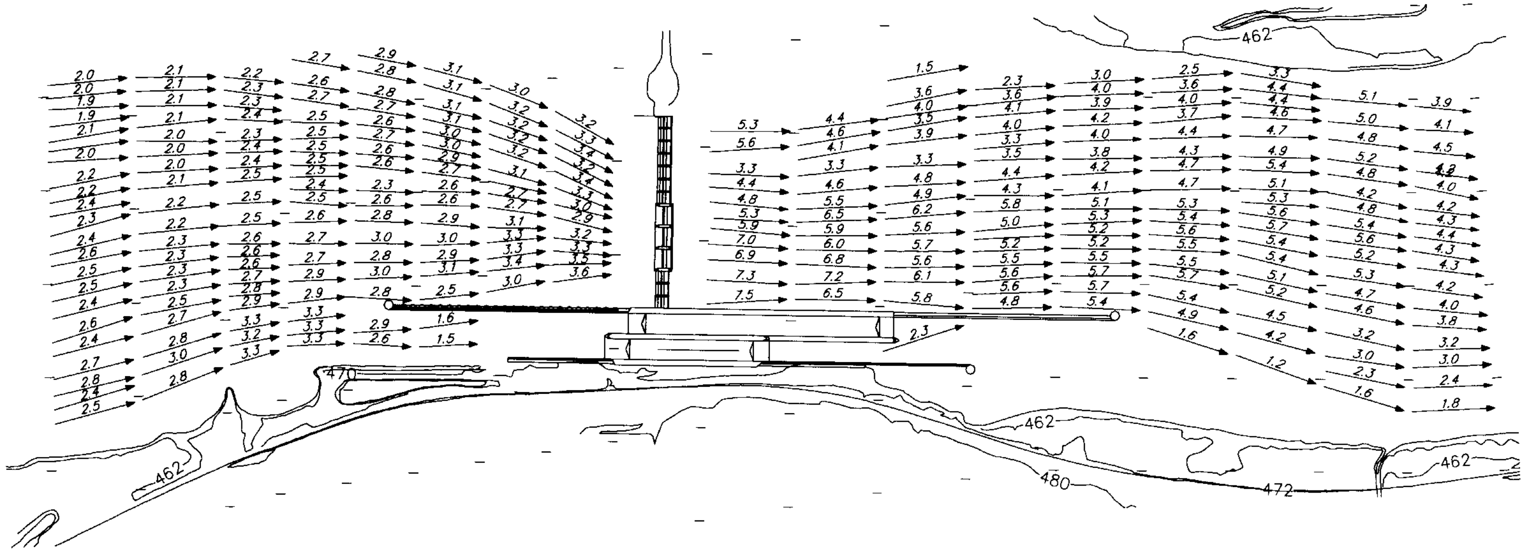
PROTOTYPE 0 500 1000 1500 2000

MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 3, PLAN A

DISCHARGE: 50,000 CFS
TAILWATER EL: 451.3 FT



LEGEND

- 3.5 — VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

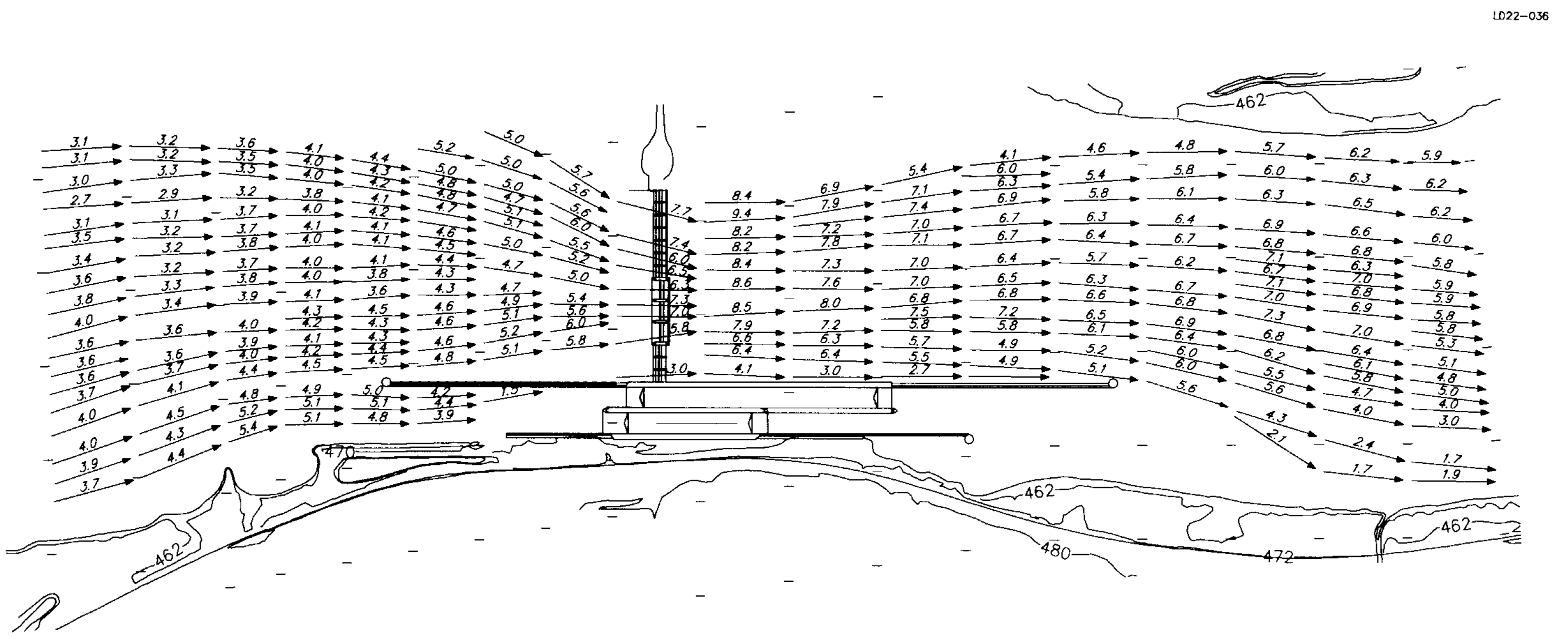
PROTOTYPE 0 500 1000 1500 2000

MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 3, PLAN A

DISCHARGE:	100,000	CFS
TAILWATER EL:	454.7	FT



LEGEND

3.5 VELOCITY IN FEET PER SECOND

VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 0 500 1000 1500 2000

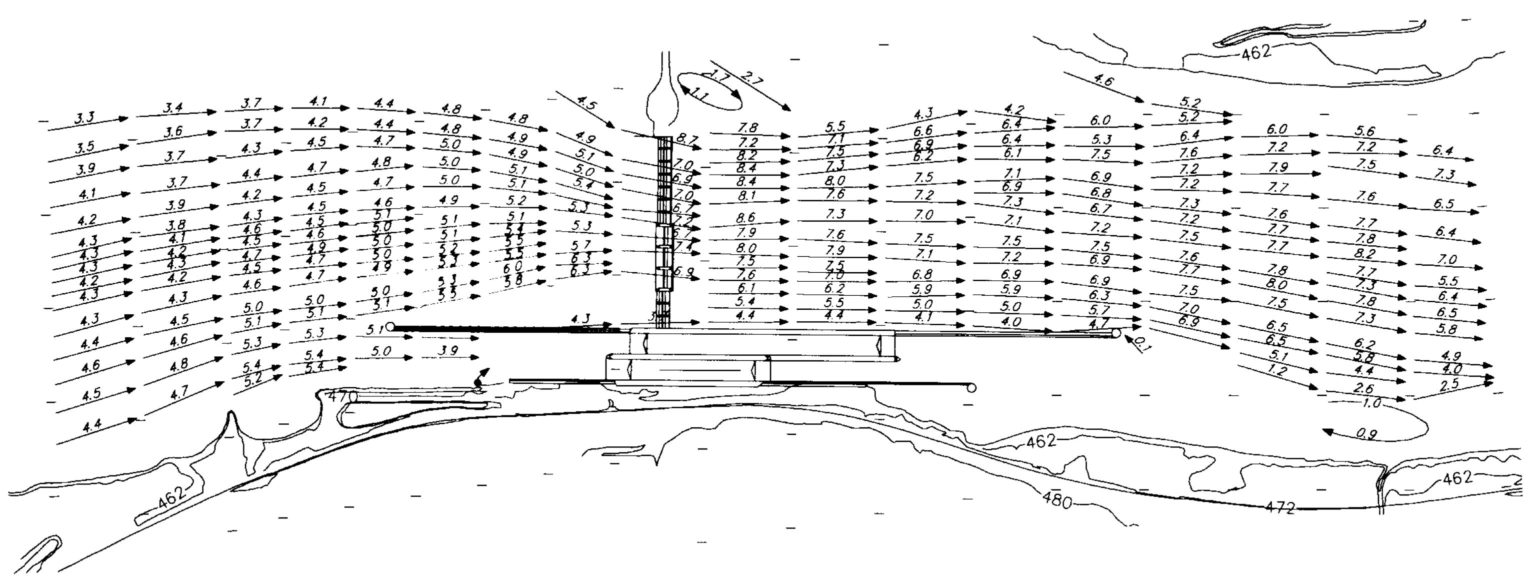
MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 3, PLAN A

DISCHARGE: 162,000 CFS

TAILWATER EL: 459.5 FT



LEGEND

3.5 VELOCITY IN FEET PER SECOND

VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 0 500 1000 1500 2000

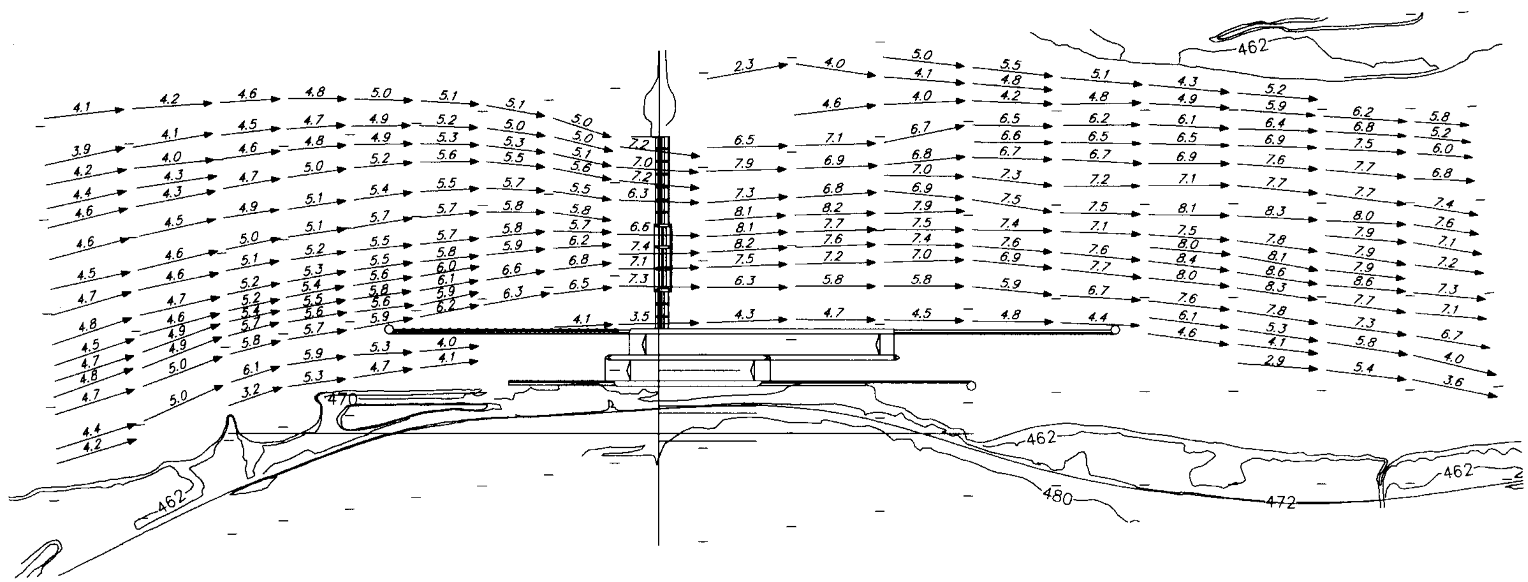
MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 3, PLAN A

DISCHARGE: 220,000 CFS

TAILWATER EL: 462.8 FT



LEGEND

3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 0 500 1000 1500 2000

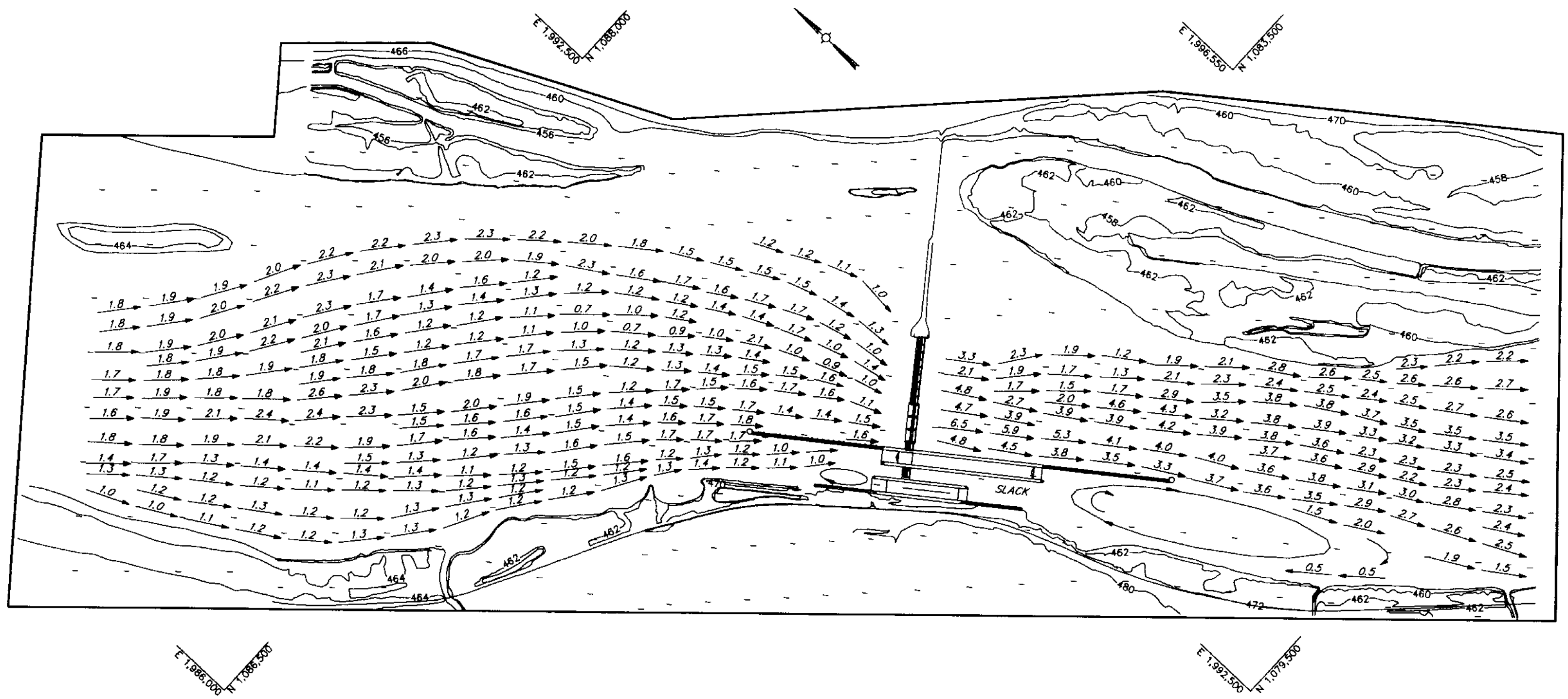
MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 3, PLAN A

DISCHARGE: 276,000 CFS
TAILWATER EL: 466.1 FT

LD22-063



LEGEND

3.5 — VELOCITY IN FEET PER SECOND

VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

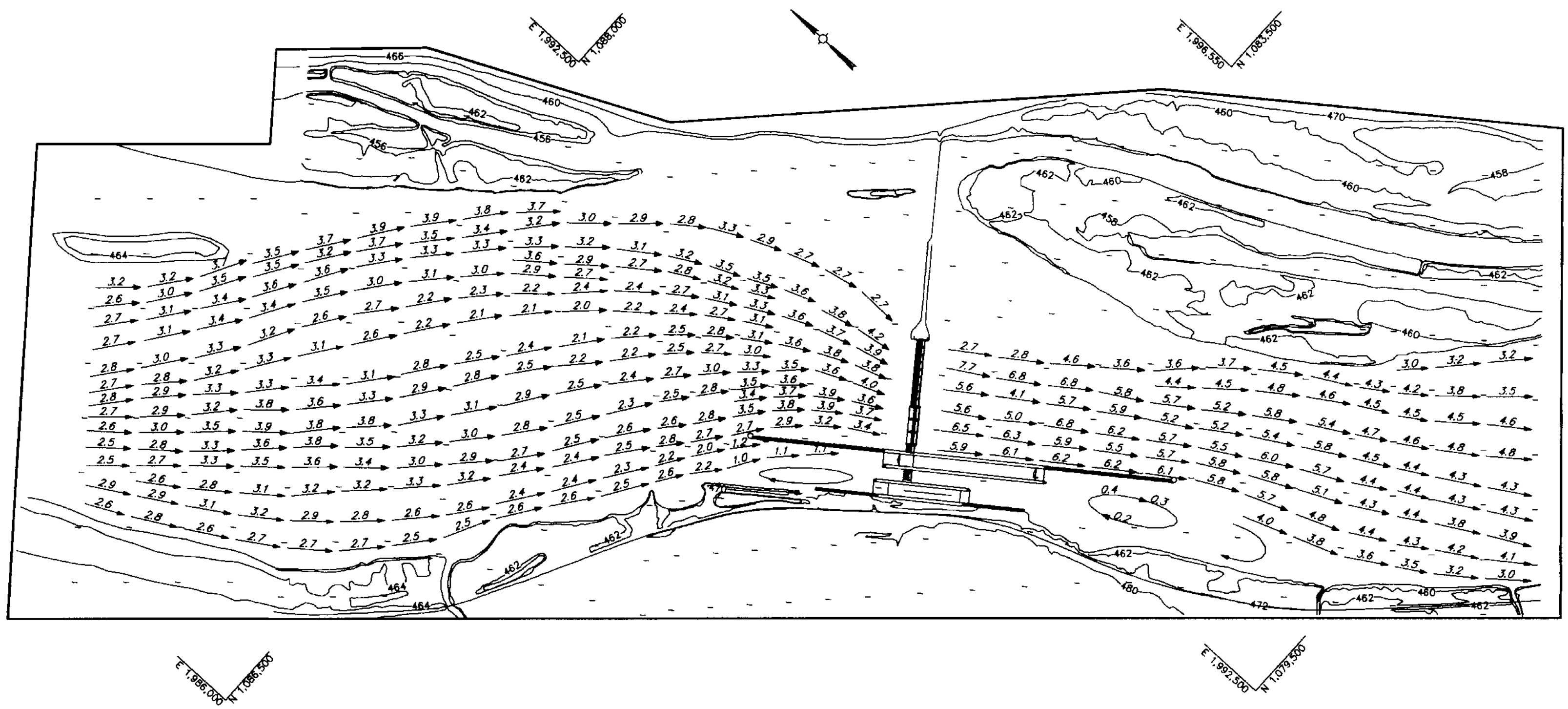
PROTOTYPE 0 500 1000 1500 2000

MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 4, PLAN A

DISCHARGE: 50,000 CFS
TAILWATER EL: 451.3 FT



LEGEND

3.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

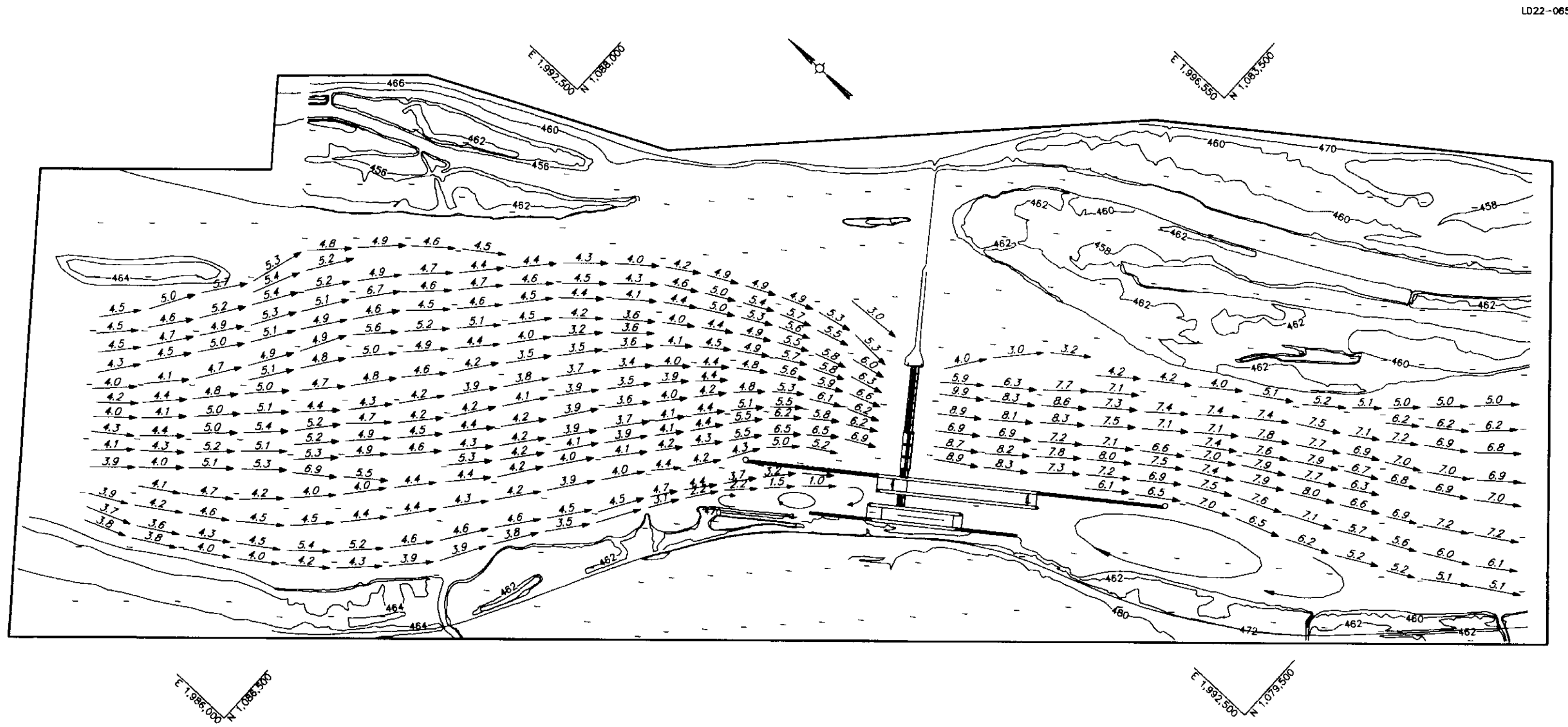
PROTOTYPE 0 500 1000 1500 2000

MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 4, PLAN A

DISCHARGE: 100,000 CFS
TAILWATER EL: 454.4 FT



LEGEND

3.5 — VELOCITY IN FEET PER SECOND

—•— VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 0 500 1000 1500 2000

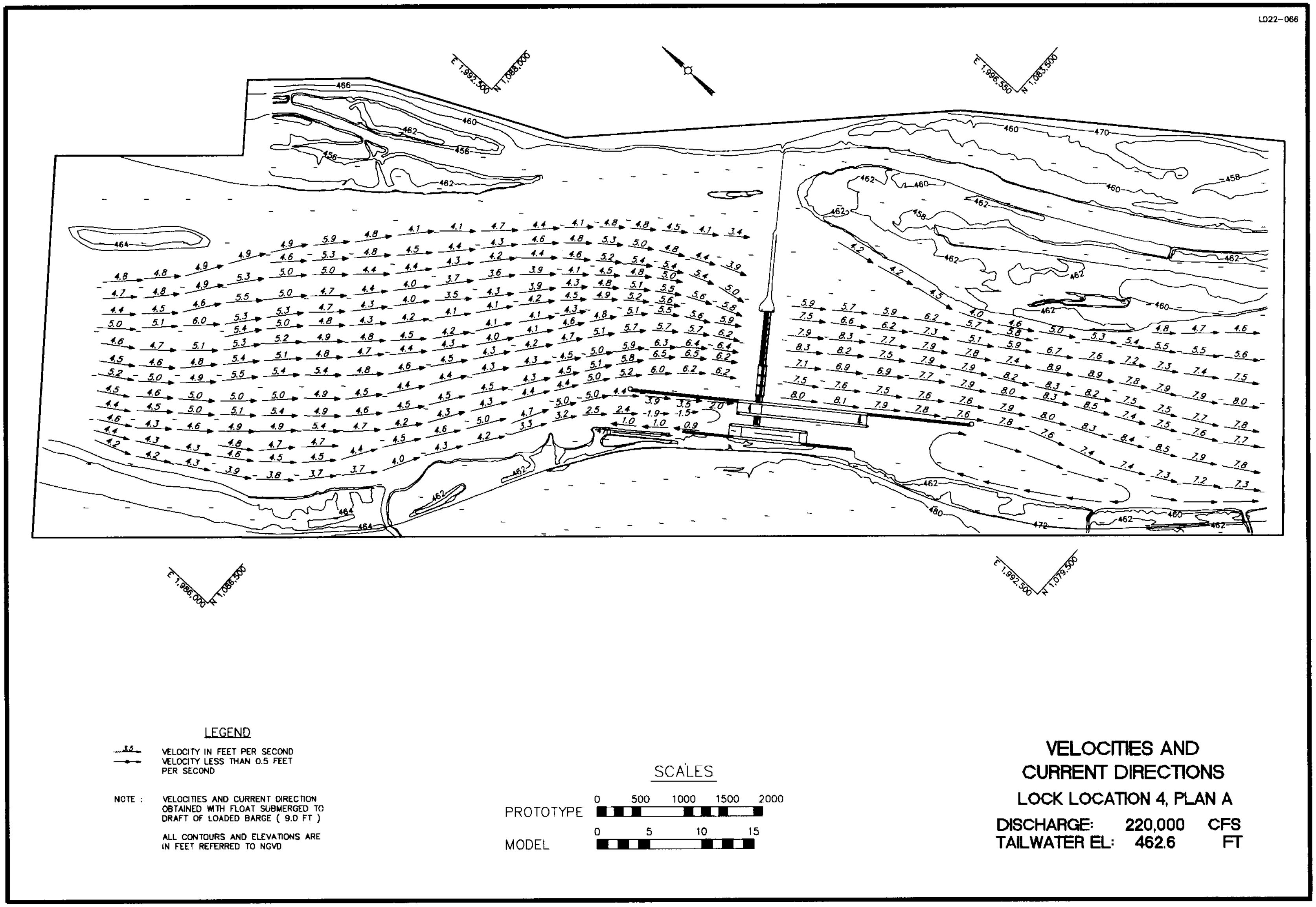
MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

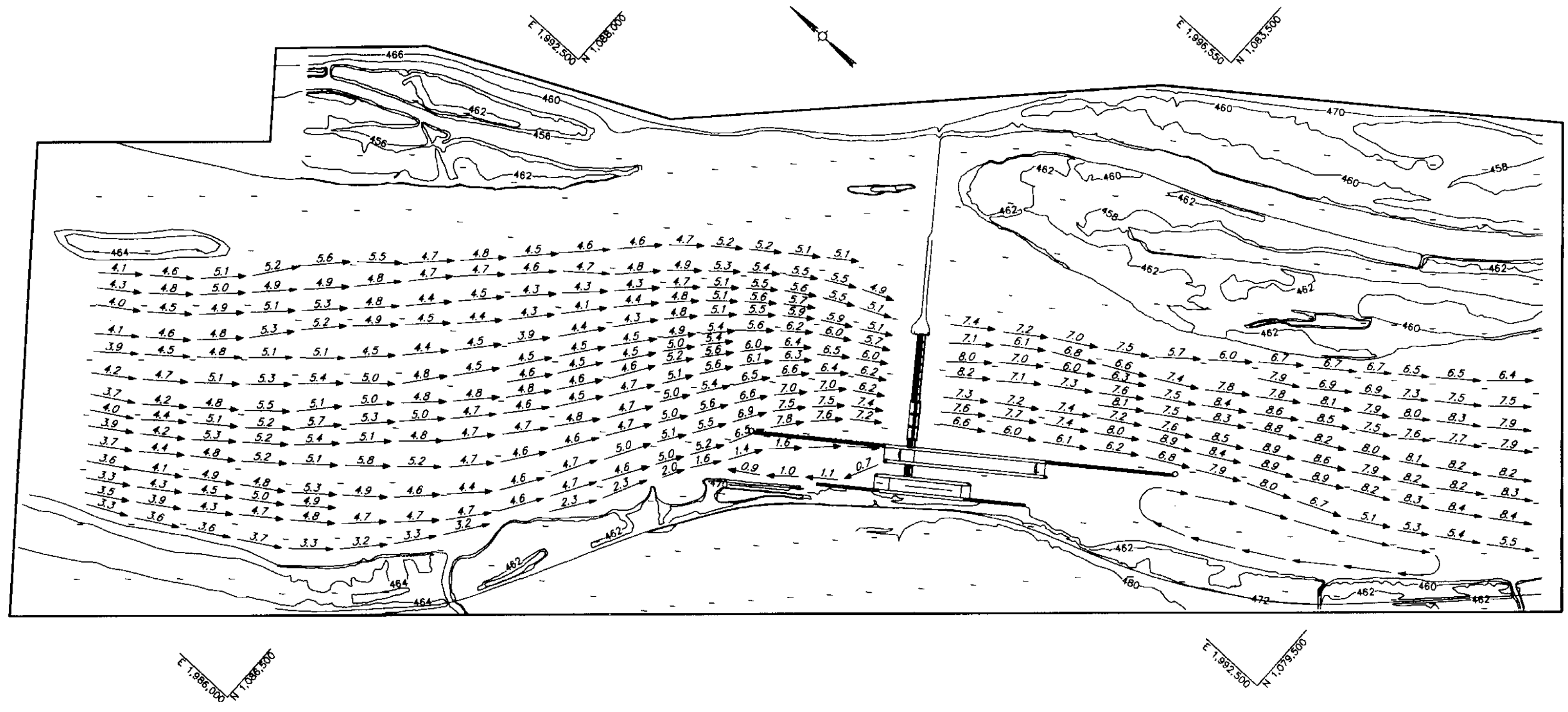
LOCK LOCATION 4, PLAN A

DISCHARGE: 162,000 CFS

TAILWATER EL: 458.6 FT


LD22-066
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)
ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD
SCALES
PROTOTYPE 0 500 1000 1500 2000
MODEL 0 5 10 15
VELOCITIES AND CURRENT DIRECTIONS
LOCK LOCATION 4, PLAN A
DISCHARGE: 220,000 CFS
TAILWATER EL: 462.6 FT

LD22-067



LEGEND

3.5 — VELOCITY IN FEET PER SECOND

VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 0 500 1000 1500 2000

MODEL 0 5 10 15

VELOCITIES AND CURRENT DIRECTIONS

LOCK LOCATION 4, PLAN A

DISCHARGE: 276,000 CFS

TAILWATER EL: 465.8 FT

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1.AGENCY USE ONLY ***(Leave blank)***

2.REPORT DATE
October 1997

3.REPORT TYPE AND DATES COVERED
Final report

4.TITLE AND SUBTITLE
Navigation Conditions at Lock and Dam 22, Mississippi River;
Hydraulic Model Investigation

5.FUNDING NUMBERS

6.AUTHOR(S)
Ronald T. Wooley

7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8.PERFORMING ORGANIZATION REPORT NUMBER
Technical Report
CHL-97-27

9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer District, Rock Island
Clock Tower Building
P.O. Box 2004
Rock Island, IL 61204-2004

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11.SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a.DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b.DISTRIBUTION CODE

13.ABSTRACT ***(Maximum 200 words)***

Lock and Dam 22 is located on the Mississippi River, 301.2 miles upstream of its confluence with the Ohio River. The principal existing structures are the main 110- by 600-ft lock located along the right descending bank, an incomplete auxiliary lock located riverward of the main lock, and a 1,024-ft-long dam with ten 60-ft-wide tainter gates and three 100-ft-wide roller gates. An overflow dike with top elevation of 459.5 (elevations (el) are in feet referred to the National Geodetic Vertical Datum) extends from the dam to high ground on the left bank. The dam provides a navigation pool that extends upstream about 24 miles to Lock and Dam 21. The dam is operated to maintain a navigation pool of el 459.5 at the dam. As the riverflow increases, the gates are raised so the normal pool el 459.5 will not be exceeded. A fixed-bed model reproduced about 3.5 miles of the Mississippi River and adjacent overbank from about 10,700 ft upstream to about 7,700 ft downstream of the existing dam to an undistorted scale of 1:120.

Three locations are being considered for a new lock at Dam 22. The model investigation was concerned with evaluating navigation conditions for each lock location and identifying any needed modifications to the navigation channel alignment, guard wall lengths, or remedial structures. This information will also be used in the preliminary design of locks at other dam sites along the upper Mississippi River. Results of the investigation revealed that with all locations a system of dikes along

(Continued)

14.SUBJECT TERMS

Fixed-bed models	Locks (Waterways)
Hydraulic models	Mississippi River
Lock and Dam 22	Navigation conditions

15.NUMBER OF PAGES
87

16.PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18.SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19.SECURITY CLASSIFICATION OF ABSTRACT

20.LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

13. (Concluded).

the left bank and a ported upper guard wall would reduce the outdraft, eliminate the need for a helper towboat, and improve navigation conditions for tows entering and leaving the upper lock approach. Lock Location 2 would require a ported upper guard wall and extensive modification of the right bank to provide satisfactory navigation conditions for tows entering and leaving the upper lock approach. Marginally acceptable navigation conditions for tows entering the upper lock approach could be established at Lock Location 3 by adding a guard wall, but also adding a system of dikes would improve navigation conditions considerably. A ported upper guard wall without a system of dikes or any modification to the existing bank would provide acceptable navigation conditions for tows entering the upper lock approach, but adding a system of dikes would improve navigation conditions.